PB85-216521

New Jersey Industrial Waste Study (Waste Projection and Treatment)

IT Enviroscience, Inc., Knoxville, TN

Prepared for

Environmental Protection Agency, Cincinnati, OH

May 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB85-216521

EPA/600/6-85/003
May 1985

NEW JERSEY INDUSTRIAL WASTE STUDY

(Waste Projection and Treatment)

by

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NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA/600/6-85-003

2.

3. RECIPIENT'S ACCESSION NO.
PB85-216521

4. TITLE AND SUBTITLE
New Jersey Industrial Waste Study
(Waste Projection and Treatment)

5. REPORT DATE
May 1985

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
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T. Busmann M. Foster

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
IT Corporation
312 Directors Drive
Knoxville, Tennessee 37923

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-03-3027
Assignment 5

12. SPONSORING AGENCY NAME AND ADDRESS
Hazardous Waste Engineering Research Laboratory
Office of Research and Development
U. S. EPA
Cincinnati, Ohio 45268

13. TYPE OF REPORT AND PERIOD COVERED
Final

14. SPONSORING AGENCY CODE
EPA/600/12

15. SUPPLEMENTARY NOTES
Project Officer: Mary Stinson (201/321-6683)

16. ABSTRACT

This study demonstrates a procedure for projecting the hazardous waste shipped off-site by industry. The projection system develops ratios of hazardous waste per employee by SIC code. These ratios can be used to estimate the hazardous waste shipped off-site for any industrial area in the United States. Wastes are categorized for each SIC code, and treatment technology options are designated for each classification.

This specific New Jersey Industrial Waste Study projects that in five years New Jersey industry will ship 558,000 tons of hazardous waste off-site per year. This study indicates that incineration with multi-purpose rotating kilns would be the most practical method of treatment for the largest amount of waste disposed of at a regional facility. It is further indicated that secure landfill will be needed, primarily for heavy metals. Economics for treatment options are also presented.

This report was submitted in fulfillment of Contract No. 68-03-3027, Work Assignment No. 5 by IT Corporation in cooperation with the Research and Development Council of New Jersey under the sponsorship of the U.S. EPA. This report is based on data collected during 1983, and work was completed in June 1984.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT
Release to Public

19. SECURITY CLASS *(This Report)*
Unrestricted

20. SECURITY CLASS *(This page)*
Unrestricted

21. NO. OF PAGES
121

22. PRICE

EPA Form 2220-1 (9-73)

DISCLAIMER

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report describes a model procedure undertaken in the state of New Jersey for projecting off-site industrial waste for any industrial area in the United States. Wastes are projected by classification, and a determination is made of the technology and capacity requirements for regional waste disposal and treatment facilities. This report will be useful to EPA and to the State and Regional programs dealing with treatment and disposal of off-site wastes.

For further information, please contact the Alternative Technologies Division of the Hazardous Waste Engineering Research Laboratory.

David G. Stephan, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

This study demonstrates a procedure for projecting the amount and classifications of hazardous waste shipped off-site by industry. The projection system develops ratios of hazardous waste per employee by SIC code. These ratios can be used to estimate the hazardous waste shipped off-site for any industrial area in the United States. Wastes are categorized for each SIC code, and treatment technology options are designated for each classification.

This specific New Jersey Industrial Waste Study projects that in five years New Jersey industry will ship 558,000 tons of hazardous waste off-site per year. This study indicates that incineration with multi-purpose rotating kilns would be the most practical method of treatment for the largest amount of waste disposed of at a regional facility. It is further indicated that secure landfill will be needed, primarily for heavy metals. Economics for treatment options are also presented.

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ACKNOWLEDGMENT

We wish to acknowledge the cooperation, guidance, and direct effort supplied to this study by the Research and Development Council of New Jersey, a nonprofit organization of industrial and academic research laboratories with liaison to agencies of the state government of New Jersey. The original and continuing objective of the R&D Council is to provide New Jersey with technical data that will assist it in developing industrial waste management plans and facilities. IT Enviroscience (ITE) has drawn upon the expertise of the R&D Council Task Force, which has the unique qualifications of representing an extraordinary cross-section of producers of industrial waste, as well as representatives from academia and state government, all of whom have provided input for the planning and execution of this study.

ITE's primary contacts with the R&D Council have been Allan Jacobs, Chairman of the Hazardous Waste Task Force of the R&D Council; Samuel J. Faiello, R&D Council Project Manager; and Dr. John Liskowitz, Chairman of the Task Force Survey Subcommittee. The R&D Council Task Force and Survey Subcommittee worked as a team with ITE to identify the industrial survey sites, develop the waste survey, submit the survey to industry, stimulate responses, evaluate responses, fill data gaps, and review the study results. They also collaborated with the EPA throughout the project to provide evaluation and guidance for the work ITE performed. The R&D Council Hazardous Waste Task Force and the companies they represent are listed in Appendix A.

SECTION 1

INTRODUCTION

PURPOSE

The objective of this study was to develop a model procedure for projecting the amount of hazardous waste, by category, shipped off-site by industry. Waste/employee/SIC factors were developed to provide a waste projection mechanism for each industry indentified by SIC code in any area of the United States. All wastes were identified by category, and treatment technologies were defined for incorporation in regional facilities to treat and dispose of off-site industrial hazardous waste.

The study was conducted in New Jersey to provide data for decisions concerning the construction of regional hazardous waste treatment facilities for industry use. The relative cost effectiveness of applicable treatment technologies are assessed.

BACKGROUND

The large concentration of waste-generating industries in some states presents an environmental hazard for those states if the wastes are not managed in an environmentally sound manner. New Jersey is one such state. Though New Jersey is small, it is the most densely populated state and is a leader in industry. Nearly every major industry in the state ranks nationally among the top ten in production volume. The New Jersey industries generate large amounts of waste containing hazardous and toxic constituents. More options for treatment of hazardous waste are needed.

Under EPA regulations, widely used ocean dumping will be phased out and those wastes that are presently dumped will have to be handled by other means. Unfortunately, there is a lack of waste treatment facilities in the state and concentrated wastes are shipped out of state for disposal. Space must be designated for siting of new treatment facilities.

The situation in New Jersey as well as in many industrialized states has created the need to seek a scientific and practical approach to development of a plan for managing industrial waste. The results of a study done in one state can be applied to other states throughout the country. The waste characteristic/ treatability matrix developed by this study should provide guidance to industry and to permit writers in industrialized states.

The primary reason New Jersey was selected for this study was that the major industries in New Jersey offered to contribute significantly to such a study through their nonprofit organization, The Research and Development Council of New Jersey. The R&D Council of New Jersey offered to work as a team with IT Enviroscience (ITE) to identify the industrial survey sites, develop the waste survey, submit the survey to industry, stimulate responses, evaluate responses, fill data gaps, review the study results, and collaborate with the EPA to provide guidance throughout the project (see Acknowledgments and Appendix A).

The need for this study was recognized by the EPA, industry, the New Jersey Department of Environmental Protection, the Governor of the State of New Jersey, and all who are concerned with the welfare and ecology of the State of New Jersey. The State of New Jersey, the Hazardous Waste Advisory Council, and the Hazardous Waste Facilities Siting Commission consider the results of this study to be an important basis for the decisions they will make concerning hazardous waste plans including the design, siting, treatment technologies, and management of regional hazardous waste disposal facilities. The information developed for the State of New Jersey by this study can be used in other industrialized areas of the nation.

SECTION 2

SUMMARY

The survey of industries conducted by the New Jersey R&D Council indicates that, including trash and on-site disposal, approximately 9 million tons per year (TPY) of industrial waste is generated in New Jersey. The quantity of waste in each category is presented in Section 5. The 5-yr projection of off-site waste, excluding trash, is 558,180 TPY that have potential for regional hazardous waste facilities. This is approximately 14% less than the present state-wide off-site waste projection. The emphasis throughout this study is directed to the identification, characterization, and disposal of the 5-yr projection of off-site waste. The R&D Council survey and the study format have been designed to supply data that will impact decisions concerning the construction of regional hazardous waste treatment facilities for industry use.

The survey results have been used to develop TPY/employee factors for specific SIC codes that may be useful for estimating off-site waste in any areas where industries classified by these SIC codes are in operation.

Based on the study results it is projected that the most practical disposal methods for the off-site waste will be as follows:

Disposal Method	Tons Per Year
Incineration	201,000
Secure landfill	61,000
Other land treatment	50,000
Resource recovery	61,000
Physical treatment	67,000
Chemical treatment	84,000
Biochemical treatment	34,000
	558,000

The study results (Section 4) contain a series of tables that present the quantity of waste by several classifications listed by SIC code for all waste disposed of off-site in New Jersey. The treatment technologies and treatability matrices used for the disposal of industrial waste and the relative cost ranges for these technologies are presented in Section 5. The details of the off-site waste projection by SIC code and the format for using the industrial waste survey data to describe and characterize the waste are presented in Section 4. The 5-yr off-site waste projection by county is presented in Section 6. The full R&D Council industrial waste survey is included in Appendix B.

Incineration with multi-purpose rotary kilns is the most practical method of treatment for the largest amount of waste to be disposed of at a regional facility, and a secure landfill will be needed, primarily for heavy metals. A review of the cost for these disposal services indicated that the 1982 disposal charges were $270/ton for incineration and $300/ton for secure landfill (not including stabilization/solidification which may be desirable).

There is need for chemical/physical treatment including neutralization, precipitation, and biochemical treatment. The need for recovery systems for solvents, oils, or metals will depend on the availability of other facilities providing these services. Provision for land treatment for biodegradation of waste should be given further consideration.

SECTION 3

STUDY BASIS

STUDY OVERVIEW

Throughout the study it was recognized that the results were to be used as a data base to make decisions concerning the construction of regional hazardous waste treatment facilities for industry use. The data are needed to establish facility locations, treatment and disposal technologies, and preliminary design capacities. To ensure that the hazardous waste classifications were not restricted to RCRA hazardous waste definitions and to improve the number of survey responses obtained, the study was established to address industrial waste rather than hazardous waste. The inclusion of industrial trash recognizes the expected trend toward shifting contaminated trash from municipal landfills to regional hazardous waste facilities. Small generators may need to rely on regional facilities for such functions as bio-treatment or simple separations which are performed on site by the large industries. It was concluded that industrial waste for regional facilities must start with the broad definition "All Industrial Wastes That Have Potential for Regional Hazardous Waste Facilities."

If all plant trash and all aqueous streams that could benefit from treatment were included in the estimated waste load for regional facilities, the facilities would obviously be extremely oversized for landfill and aqueous treatment. It is not likely that uncontaminated trash (paper, wood, rubble, etc.) will ever be a candidate for a centralized regional facility, and there are no grounds at this time for assuming that all contaminated trash will be eliminated from municipal or on-site landfills. It also appears reasonable to assume that where aqueous streams could benefit from treatment such as settling or bio-treatment, only a small portion of them will be serious candidates for a regional facility. It would also be an error to neglect the indication that an increasing portion of industrial waste now going to municipal landfills will go to regional facilities as well as a portion of the contaminated aqueous streams that could benefit from bio-treatment or simple separations. The study includes all waste that is shipped off site for disposal, but retains the waste identity so each category can be selected as desired for regional facility design.

The study was conducted in the following phases:

- Data review
- Survey design
- Survey site selection
- Survey submission
- Treatment technologies
- Study results

To present the data in the most clearly understood terms and to avoid the confusion of multiple units, the data throughout the report are expressed in English units. A metric system conversion table is included in Appendix C.

DATA REVIEW

The first step was to review the work that had been performed which might relate to New Jersey industrial waste. Previous work included studies by the (1) Delaware River Basin Commission, (2) the Princeton University Report on Industrial Waste Disposition in New Jersey by Anne Kruger, and (3) national EPA reports and studies for New York, New England, and California. These studies were helpful in bringing the task into perspective and as guides when developing the survey design and data collection methodology.

The R&D Council of New Jersey had directed a considerable amount of work toward identifying the information needed for an industrial survey that would determine the treatment technologies to be incorporated in a regional waste treatment facility. The decision chart the R&D Council developed as a precursor to the survey questionnaire form developed during this study is included in Appendix D.

SURVEY DESIGN

The New Jersey R&D Council Industrial Waste Survey developed during this study and sent to 601 industrial sites is included as Appendix C of this report. The decision chart prepared by the R&D Council (Appendix D) was the basis for developing the industrial waste survey. A treatment technology matrix was devised correlating the practical waste treatment technologies available with the categories of waste appropriate for each treatment technology (Table 1). Table 2 was created to indicate the waste characteristics within each category that would impact on the appropriate waste treatment technology decision. An industrial waste survey was then developed that would provide a mechanism for grouping the waste into the desired categories and characterizations. Table 3 indicates the survey questions designed to obtain the data required to satisfy the matrix of waste treatment technologies applicable for the waste categories and waste characteristics for all industrial waste generated in New Jersey that might reasonably be considered candidates for a regional industrial waste treatment facility.

The survey does not include any radioactive material or aqueous streams going to internal or outside treatment by pipeline. Although we are interested in a general assessment of waste disposed of on site, the primary interest is in those wastes that have potential of being disposed of at a regional facility. This is a key point that makes this survey more valuable as opposed to traditional studies which have projected the total waste generated and then attempted to estimate the waste shipped off site. There can be extreme variations in the amount generated versus the amount shipped off site.

TABLE 1. REGIONAL INDUSTRIAL WASTE FACILITY PRACTICAL TREATMENT TECHNOLOGIES AND APPLICABLE WASTE CATEGORIES

	Aqueous Inorganic	Aqueous Organic	Organic Liquid	Organic Solid	Inorganic Solid	Organic Sludge/ Slurry	Inorganic Sludge/ Slurry	Used Oil	Spent Solvent	Metal Waste	Facility WW
Aqueous organic/inorganic											
Steam stripping		X							X		
Carbon adsorption		X									X
Extraction		X	X						X		
Emulsion breaking		X	X					X			
Alkali/acid hydrolysis		X									
Chemical precipitation	X	X									
Chemical oxidation	X	X									
Neutralization	X	X									X
Biological treatment		X									
Solvent chem. recovery											
Distillation			X					X	X		
Evaporation			X					X	X		
Oil reprocessing								X			
Sludge dewatering						X	X				
Incineration		X	X	X		X		X	X		
Rotary kiln		X	X	X		X		X	X		
Liquid		X	X					X	X		
Chlorinated liquid		X	X					X	X		
Other (sludge)		X	X	X		X		X	X		
Stabilization	X				X		X			X	
Secure landfill					X		X			X	
Metal reprocessing							X			X	

TABLE 2. REGIONAL INDUSTRIAL WASTE FACILITY WASTE CHARACTERISTIC REQUIREMENTS FOR EACH TECHNOLOGY AND APPLICABLE WASTE CATEGORY

Technology	Applicable Waste Categories	Waste Characteristics
Steam stripping	Aqueous organic	% Organic, type organic
Carbon adsorption	Aqueous organic	% Organic, type organic
Extraction	Aqueous organic, organic liquid, spent solvent	% Organic, type organic
Emulsion breaking	Aqueous organic, used oil, organic liquid	% Oil, % organic
Alkaline/acid hydrolysis	Aqueous organic	% Organic, type organic
Chemical precipitation	Aqueous inorganic, aqueous organic	% Metals, type metals
Neutralization	Aqueous inorganic, aqueous organic	% Acid/base, type acid/base
Chemical oxidation	Aqueous organic, aqueous inorganic	% Organic, % CN, type organic
Biological oxidation	Aqueous organic	% Organic, type organic
Distillation	Organic liquid, spent solvent, used oil	% Organic, type organic
Evaporation	Organic liquid, spent solvent, used oil	% Organic, type organic, oil
Oil reprocessing	Used oil	Type oil
Sludge dewatering	Organic slurry/sludge, inorganic slurry/sludge	% Solids, % water, type organic
Incineration	Aqueous organic, organic liquid, organic solid, organic sludge/slurry, used oil, spent solvent	% Organic, % aqueous, % inorganic, % chlorine, S, N, P, type organics, % NaCl, % salts
Stabilization	Aqueous inorganic, inorganic solid, inorganic sludge/slurry, metal waste	% Water, % inorganic, type inorganic, % organic
Secure landfill	Inorganic solid, inorganic sludge/slurry metal waste, stabilized waste	% Water, % organic, % inorganic
Metal reprocessing	Inorganic solid, inorganic sludge/slurry metal waste	% Inorganic, % water, type inorganic

TABLE 3. INDUSTRIAL SURVEY QUESTIONS DESIGNED TO OBTAIN DATA REQUIRED FOR TECHNOLOGY/APPLICABLE WASTE CATEGORY/ WASTE CHARACTERISTICS

Technology	Aqueous Inorganic	Aqueous Organic	Organic Liquid	Organic Solid	Inorganic Solid	Organic Sludge/ Slurry	Inorganic Sludge/Slurry	Used Oil	Spent Solvent	Metal Waste
Steam stripping		11,12A,C,17								
Carbon		11,12A,19								
Extraction		11, 12A	11,12A,17						11,12A,17	
Emulsion Breaking		12A,14	10,12A,C					10,12A,C, 14,16		
Alkali/acid hydrolysis		11,12A,B								
Neutralization	10,12A,13	10,12A,24								
Chemical precipitation	12A,C,15,16	12A,C,15,16								
Biological treatment	12A	12A,18,19, 20,21								
Chemical oxidation		11,12A,20								
Distillation		11,12A	11,12A,14,17						11,12A,17	
Evaporation			11,12A,14,17							
Oil reprocessing								11,12A,14		
Sludge dewatering			10,11,12A			10,11,12A,C	10,11,12A,C, 15,16			
Incineration		3,5,10,12A, B,C,11,22	3,5,10,12A, B,C,11,22	3,5,10,12A, B,C,11,22		3,5,10,12A, B,C,11,22		11,12A,B,C 14,22	11,12A,B,C, 17,22	
Rotary kiln		3,5,10,12A, B,C,11,22	3,5,10,12A, B,C,11,22	3,5,10,12A B,C,11,22		3,5,10,12A, B,C,11,22		11.12A,B,C 14,22	11,12A,B,C 17,22	
Liquid		3,5,10,12A B,C,11,22	3,5,10,12A B,C,11,22	3,5,10,12A, B,C,11,22		3,5,10,12A, B,C,11,22		11,12A,B,C 14,22	11,12A,B,C 17,22	
Chlor. liquid		3,5,10,12A, B,C,11,22	11,12A,B,C	11,12A,B,C		3,5,10,12A, B,C,11,22		11,12A,B,C 14,22	11,12A,B,C 17,22	
Other (sludge)		3,5,10,12A, B,C,11,22	11,12A,C,C, 22,	11,12A,B,C, 22,		3,5,10,12A, B,C,11,22		11,12A,B,C 14,22	11,12A,B,C 17,22	
Stabilization	11,12A,C				10,11,12A, C,15,16		10,11,12A C,15,16			
Secure landfill					10,11,12A, C,15,16		10,11,12A C,15,16			
Metal reprocessing					10,11,12A C,15,16		10,11,12A C,15,16			11,12A,C 15,16

The number listed indicates the survey question number requesting data for the specified category.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
U.S. GOVERNMENT PRINTING OFFICE: 1980-660-639
TYPING GUIDE SHEET

To form a basis for projecting the off-site waste generated throughout the state, it was vital that each survey respondent provide the primary SIC code of the facility generating the waste and the approximate number of employees at the site. Through this methodology waste/employee factors were generated that are specific for each waste category or characterization within each SIC code. The factors were then used to project the annual industrial waste generation for the entire state by using the listed number of employees/SIC code for all industries as reported in the County Business Patterns for New Jersey (U.S. Bureau of Census). This method of projection results in a higher degree of accuracy than dollar sales projections used in previous surveys because dollar sales are normally not available (especially at intermediate manufacturing sites) and are frequently rough estimates based on the number of employees. Employee figures from various sources are in relatively good agreement. The survey employee questions were styled to fit the County Business Patterns system.

Several survey features were designed to encourage a good response from industry. Wherever practical, "check-the-box" type questions were used. No process or production data were required and only readily available waste data were requested.

The survey was designed through the combined efforts of ITE and the R&D Council Task Force Survey Subcommittee listed in Appendix A. The survey was submitted to selected subcommittee member companies as a field test. After some clarification modifications the survey was submitted to the selected industrial sites.

SURVEY SITE SELECTION

The objective of the survey site selection was to obtain data from enough industry locations to develop waste/employee/SIC code factors to allow a projection of the potential waste from each significant industry in New Jersey. It was determined to be most important to obtain responses from the major industries on the state's hazardous waste manifest list. A total of 1046 company locations appeared on the manifest list. Of this total, 144 companies accounted for more than 90% of the hazardous waste shipments reported.

The U.S. EPA Region II RCRA list of 294 companies in New Jersey was reviewed and rejected because it primarily identified on-site treaters and disposers and did not identify the generators that ship off site.

It was important to have all significant sectors of industry surveyed and to provide a factoring mechanism to project the waste load for the entire state, the majority of the survey sites were selected by reviewing the computer data base compiled by Economic Information Systems, Inc. which lists New Jersey industries ranked by sales volume for each 4-digit SIC code. The SIC code review revealed that 77% of all RCRA and manifest sites are covered by the following SIC codes:

28 - Chemicals and Allied Products
29 - Petroleum Refining and Related Industries
33 - Primary Metal Industries
34 - Fabricated Metal Products, Except Machinery and Transportation Equipment
36 - Electrical and Electronic Machinery, Equipment, and Suppliers

The major waste load is generated by the 28 and 29 SIC groups. Enough survey sites were selected from the list of industries within SIC codes 28 and 29 to cover 80% of the sales volume for each 4-digit SIC code within the two groups. Survey sites were selected from the list of industries within SIC codes 33, 34, and 36 to cover 80% of the sales volume for the major 4-digit SIC codes and at least one company for every 4-digit SIC code within these groups. The companies representing 80% of the sales volume for the following SIC codes were also selected for inclusion in the survey:

2491 - Wood Preserving
3292 - Asbestos Products
3711 - Bodies, Motor Vehicles and Passenger Cars
1310 - Crude Petroleum and Natural Gas

The highest sales companies in several other SIC code classifications were also included. A total of 601 sites were selected to receive survey questionnaires from the R&D Council. The 601 sites included 152 sites from the state's waste manifest list which account for more than 90% of the hazardous waste shipped, and approximately 150 small generator sites with less than 50 employees.

SURVEY SUBMISSION

To explain the reason for the survey and to encourage a high response from industry, the New Jersey R&D Council sent a cover letter (Appendix E) with each survey questionnaire. The R&D Council submitted these surveys to 601 industrial sites in New Jersey, and the completed questionnaires were returned directly to the R&D Council. The R&D Council then assigned a respondent code number and removed the company identification before sending each completed response to ITE for processing. ITE and the EPA do not have access to the company identifications.

To improve the quantity and quality of responses, the R&D Council Task Force members each took a portion of the 601 companies surveyed and personally contacted each company to offer assistance and encourage cooperation with the survey.

The New Jersey Chemical Industry Council was helpful by encouraging their members to respond to the survey. Significant cooperation and encouragement were also obtained from trade organizations, the New Jersey Hazardous Waste Facilities Siting Commission, and the Hazardous Waste Advisory Council.

SECTION 4

STUDY RESULTS

The results of the New Jersey R&D Industrial Waste Survey are presented in this section. Survey responses were obtained from 183 (30%) of the 601 industrial sites surveyed. Responses were obtained from 71% of the sites accounting for more than 90% of the hazardous wastes shipments reported by the state's waste manifest list. Responses were obtained for 81% of the top 32 sites on the manifest list. For the SIC code groups that account for 80% of the off-site wastes, the respondents represented 55,415 employees or 44% of the toal 124,687 employees in these groups. The results, discussion, and conclusions are organized to place the emphasis on data that have the most impact on decisions concerning the construction of regional hazardous waste treatment facilities for industry use. Data were collected to assess the amount of waste generated and disposed of on-site, but the emphasis throughout the study is on industrial waste that has potential for regional facilities. All survey results are presented in sequence as they appear in the survey form included as Appendix B.

To develop a projection of all industrial waste for the entire state of New Jersey and to create a mechanism for waste data projection throughout the United States, tons per year (TPY)/employee factors were developed for each SIC code. These escalation factors were developed by requesting the respondents to indicate the number of employees and SIC codes used at each responding site. The employee assignments were made to be consistent with the U.S. Bureau of Census County Business Patterns publication which was used to project the respondents' data by county for all of New Jersey. The TPY/employee factors are different for each SIC code and are different for each category within each SIC code. Since ratios (number of state-wide employees/number of survey respondent employees) have been established for each SIC code in New Jersey, these ratios have been used as escalation factors throughout the study to project the data for the entire state from the survey responses for each SIC code. The employee totals and SIC code escalation factors are shown in Appendix F.

Table 4 lists the total waste generated at the 161 sites that submitted a survey response. The wastes are totaled by category and on-site/off-site disposal. The categories are defined in the questionnaire (Appendix B). Table 5 lists a projection of the total industrial waste generated in New Jersey and the projected off-site versus on-site disposal. An overall escalation factor of 6.59 was used to project the state-wide total from the survey responses (523,791 state-wide employees/79,516 respondent employees). For the off-site disposal study (all of the remaining study results), indi-

TABLE 4. NEW JERSEY INDUSTRIAL WASTE SURVEY
TOTAL WASTE GENERATED
(AS REPORTED)

Category	Total (TPY)	Disposed On-Site (TPY)	Disposed Off-Site (TPY)	Percent Off-Site
Aqueous inorg. liq. (AIL)	58,165	31,236	26,929	46
Aqueous org. liq. (AOL)	947,390	930,147	17,243	2
Inorganic liquids (IL)	0	0	0	
Organic liquids (OL)	42,073	13,702	28,371	68
Inorganic slurry (ISL)	6,402	0	6,402	100
Organic slurry (OSL)	86,193	20,637	65,556	76
Inorganic solid (IS)	52,817	34,016	18,802	36
Organic solid (OS)	35,586	1,105	34,481	97
Industrial trash (IT)	142,912	13,460	129,452	91
Municipal trash (MT)	53,178	9,482	43,696	82
Total	1,424,716	1,053,785	370,931	26

Base year 1983.

TABLE 5. NEW JERSEY INDUSTRIAL WASTE SURVEY
TOTAL WASTE GENERATED
PRESENT STATE-WIDE PROJECTION

Category	Total (TPY)	Disposed On-Site (TPY)	Disposed Off-Site (TPY)	Percent Off-Site
Aqueous inorg. liq.	383,310	205,847	177,463	46
Aqueous org. liq.	6,243,299	6,129,668	113,631	2
Inorganic liquids	0	0	0	
Organic liquids	277,261	90,296	186,965	68
Inorganic slurry	42,189	0	42,189	100
Organic slurry	568,012	135,998	432,014	76
Inorganic Solid	348,064	224,165	123,899	36
Organic solid	234,512	7,282	227,230	97
Idustrial trash	941,790	88,701	853,089	91
Municipal trash	350,443	62,486	287,957	82
Total	9,388,880*	6,944,443*	2,444,437*	26

*These values are believed to be high by more than 500,000 TPY because of variation between the industry distribution of survey respondents and the actual state-wide industry distribution and because responses were considered atypical in some areas. These preliminary projections were made to approximate total waste generation and are not used as part of the off-site waste disposal study.

vidual escalation factors were applied to each SIC code and some atypical response data has been discounted. This prevents the results from being skewed by the variation between the industry distribution of survey respondents and the actual state-wide industry distribution. These points are covered in more detail in following discussions. For these reasons the overall projected totals of Table 5 are believed to be high by at least 500,000 tons per year (TPY).

The primary purpose of Tables 4 and 5 is to present a rough estimate of the total waste generated and a rough assessment of the portion disposed of off site. The survey results indicate that 26% of the industrial waste generated is disposed of off site. It is apparent that the use of an overall percentage factor to project off-site waste from total waste generated would give very misleading results. As indicated by Table 4 the portion of waste going off-site varies widely from 2 to 100%, depending on the waste category. The percentage going off site will also vary from near zero to 100% depending on the specific industry involved. The off-site percentage is also highly influenced by the inclusion or exclusion of industrial trash which can account for nearly half of the industrial waste disposed of off site.

Table 6 lists the total waste disposed of off site as reported by the survey respondents. For all off-site waste tables and results the data have been divided into two groups. The main group contains the major off-site waste producing industries including chemicals and allied products, plastics, drugs, cosmetics, paints, and petroleum products. The secondary group contains lesser off-site waste producing industries including canned foods, primary metals industries, metal products, machinery, and electrical equipment. Through extra effort and good cooperation, a very high survey response was obtained in the major group. The overall survey responses for the main group represent 44% of the state-wide industry. As shown by Table 6 the overall escalation factor for the main group is only 2.3 and the largest escalation factor for a single SIC code is 7.9.

The secondary group of industries is much more fragmented and much less important from a waste projection standpoint. The survey responses were much weaker from the secondary group and because of the high escalation factors required to develop the state-wide projection they are reported separately. The responses from the secondary group are believed to be atypical of the group, and inclusion of these data without weighing them separately would significantly weaken the study results. There is ample reason to believe that the state-wide projection based on the responses from the secondary group should be significantly lower. The EPA report "Hazardous Waste Generation and Commercial Hazardous Waste Management Capacity - An Assessment," December 1980, by Booz-Allen & Hamilton, Inc. concluded that the industries contained in this secondary group account for 21% of hazardous waste generated. The Princeton University Center for Engineering and Environmental Studies Report "Industrial Wastes: Generation and Disposition in New Jersey," May 1982, by Anne L. Kruger concluded that the SIC codes

TABLE 6. TOTAL REPORTED OFF-SITE WASTE BY SIC CODE (TPY)

SIC Code	AIL	AOL	IL	OL	ISL	OSL	IS	OS	Total TPY Waste	Employee Escalation Factor (ESC)	TPY / Employee
Primary Group											
281	1,383			57			10,825	45	12,310	2.7	7.1
282	2,238	1,100		871		23	102	2,348	6,682	1.7	2.4
283	1,971			5,816	40	32		7,447	15,306	3.9	1.8
284		472		1,307	340	223		1,900	4,242	4.7	0.8
285				1,043		117	6	179	1,345	1.1	0.3
286	1,870	5,000		12,120		20,259	195	9,102	48,546	3.8	11.9
287	52	9,567		102		10,963		2,797	23,481	2.4	57.4
289		87		293		685		339	1,404	7.9	1.6
291	7,801	1		91	5,919	26,969	2,407	1,196	44,384	3.1	28.6
299				512				27	539	1.0	0.5
971		506		492		522	400	625	2,545	1.0*	0.1
	15,315	16,733	0	22,704	6,299	59,793	13,935	26,005	160,784	2.3	2.9
Secondary Group											
203				10		4,250			4,260	26.3	18.0
306							133	2,000	2,133	26.8	12.5
33	6,978	510		40			919	41	8,488	17.1	6.6
34	2,567			442	103	85	3,650	350	7,197	15.2	2.0
35	337			3,699			2	1	4,038	9.1	0.9
36	157			25		3	19		204	11.7	0.05
739				750				754	1,504	15.4	0.4
All remaining	1,577			701		1,425	144	5,330	9,178	25.1	1.4
	11,616	510	0	5,667	103	5,763	4,867	8,476	37,002	16.5	1.53
	26,931	17,243	0	28,371	6,402	65,556	18,802	34,481	197,786	6.6	2.5

*Military - employee figures not available. Low waste makes error negligible.

contained in this secondary group account for 14% of the New Jersey industrial off-site waste. It appears safe to conclude that the off-site hazardous waste contributed by the secondary group will not exceed 20% of the total, and this overall percentage is used for all results and conclusions presented by this study. On several tables the totals for the secondary group vary significantly as a percentage of the total for the categories listed. However, all projections are based on the secondary group estimate being 20% of the overall total TPY projection.

Table 6 lists the total off-site waste by waste category for each SIC code as described above. Since the waste study is directed toward hazardous waste, industrial trash is assumed to go to a municipal landfill and has been eliminated from the off-site disposal study. If the trash was indicated to be contaminated with organic, it was placed in the organic solid category. Category and SIC code definitions are included in Appendix B.

Table 6 also lists the escalation factors used for the state-wide waste projection by SIC code and the TPY/employee factor that could be used to project waste for these SIC codes throughout the country. The employee statistics used for these factors are included in Appendix F.

Table 7 lists the total state-wide projection of off-site waste (base yr 1983) by category for each SIC code. Unless otherwise stated, throughout the study the state-wide projection, based on this 1983 survey, is a future projection adjusted to include the changes projected to occur during the next 5 years including changes in waste disposal from on-site to off-site, off-site to on-site, and expected changes in waste quantity. Table 7 includes both the present and future projection. This has been included to show that the total state-wide off-site waste quantity projection is expected to decrease by approximately 14% during the next 5 years. The total present state-wide off-site waste projection is 648,535 TPY and the 5-year projection is 558,180 TPY. The data used for adjusting the present state-wide projection to the 5-year projection were obtained from questions 7 and 8 of the survey.

Table 8 indicates the physical form of the off-site waste as it would arrive at a regional facility at normal ambient temperature (60°F). These data were obtained from question 4 of the survey. Even though the survey indicates that no waste gas is anticipated, with proper planning incineration systems could be adapted to accommodate most waste gases.

Table 9 (survey question 5) indicates the container usage anticipated for shipping off-site waste. Indications are that the great majority of off-site waste will be shipped as bulk solids and liquids. However, the total projected off-site shipments in steel drums equates to approximately 300,000 steel drums per year.

Survey question 6 supplied the off-site waste volume data used throughout this study. Data from question 6 also indicate that for each category

TABLE 7. TOTAL STATE-WIDE PROJECTION OF OFF-SITE WASTE BY SIC CODE (TPY)

SIC Code	Future (5 Yr) State-Wide Projection (TPY)[a]								Present Projection (TPY)	Future Projection (TPY)
	AIL	ADL	IL	OL	ISL	OSL	IS	OS		
Primary Group										
281	177			150			29,512	119	32,622	29,958
282	3,360			2,610		43	189	3,970	11,293	10,172
283	11,775			19,511	196	142		30,630	60,000	62,254
284		2,197		5,403	1,595	1,000		8,892	19,895	19,087
285				1,315		125	6	196	1,439	1,642
286	7,506	4,763		41,161		100,396	434	16,018	184,960	170,278
287	62	1,413		284		26,530		6,748	56,824	35,037
289		680		1,968		5,425		2,633	11,148	10,706
291		3		285	18,526	75,975	6,886	3,513	138,922	105,188
299				562				30	539	592
971		253		312		522		515	2,545	1,602
	22,880	9,309	0	73,561	20,317	210,158	37,027	73,264	520,187	446,516
Secondary Group[b]										
203				263		111,648			111,910	111,911
306							3,564	53,600	57,164	57,164
33	52,928	8,699		815		2	21,516	911	145,060	84,871
34	38,280			4,920	1,562	1,359	54,763	6,149	109,682	107,033
35	3,354			36,310			97	9	36,584	39,770
36	1,720			265		3	199		2,393	2,187
739				9,412				8,857	23,207	18,269
All remaining	19,776		6	12,825	8	20,102	3,250	145,915	230,184	201,882
	116,058	8,699	6	64,810	1,570	133,114	83,389	215,441	716,184	623,087
Est.[c]	20,799	1,559	1	11,615	281	23,856	14,944	38,609	128,348	111,664
Est. Total	43,679	10,868	1	85,176	20,598	234,014	51,971	111,873	648,535	558,180

[a] See Table 6 for symbol definition. Base year 1983.

[b] These numbers are disproportionately high - see text p. 15.

[c] Estimate based on the secondary group constituting 20% of the total off-site waste.

TABLE 8. PHYSICAL FORM OF OFF-SITE WASTE

Form At 60°F	Respondents As Reported TPY	State-Wide 5 Yr Projection TPY
Primary Group		
Liquid	54,718	105,679
Solid	38,054	102,451
Sludge/slurry	68,007	238,374
Gas	0	0
Total	160,779	446,504
Secondary Group[a]		
Liquid	18,431	46,436
Solid	13,339	53,546
Sludge/slurry	5,230	11,682
Gas	0	0
Total	37,000	111,664
Combined		
Liquid	73,149	152,115
Solid	51,393	155,997
Sludge/slurry	73,237	250,056
Gas	0	0
Total	197,779	558,168

[a] Estimated to be 20% of total. See text p. 15.

TABLE 9. OFF-SITE WASTE DISPOSAL CONTAINERS

Containers	Respondents As Reported TPY	State-Wide 5 Yr Projection TPY
Primary Group		
Bulk solids	61,037	186,545
Steel drums	14,622	59,275
Fiber drums	782	2,573
Bulk liquids	83,244	191,572
Other	511	2,550
Total	160,196[a]	442,515[a]
Secondary Group[b]		
Bulk solids	11,798	49,324
Steel drums	2,439	5,727
Fiber drums	111	346
Bulk liquids	22,852	56,858
Other	379	31
Total	37,579[a]	112,286
Combined		
Bulk solids	72,835	235,869
Steel drums	17,061	65,002
Fiber drums	893	2,919
Bulk liquid	106,096	248,430
Other	890	2,581
Total	197,775	554,801

[a] Some respondents did not indicate the type of container used. In addition, wastes may be counted more than once if more than one type of container is used.

[b] Estimated to be 20% of total. See text p. 15.

of waste shipped off-site, the average quantity shipped per site is 416 TPY. The average number of off-site shipments of each waste is 24 per year.

Questions 7 and 8 were used to develop the 5-year projections as discussed earlier in this report.

Table 10 lists the off-site waste disposal methods currently being used by the survey respondents. These data were obtained from question 9. The methods the respondents considered applicable for future disposal were incorporated in the state-wide 5-year projection. Several disposal options listed by survey question 9 were not selected by any respondents and were omitted from Table 10. The waste was included under each method listed as applicable. In some cases, up to three methods may have been indicated to be applicable for disposing of a waste. This would indicate the amounts to be considered as maximums in all cases but not be additive. However, several disposal method amounts could increase significantly by inclusion of waste that did not have a disposal method indicated. A projected 251,384 TPY of off-site waste has no waste disposal method indicated. This is 45% of the total 5-year projected total as indicated by Table 9.

Table 11 is a summary total of the characteristics selected from question 10 to describe the respondent's waste. More than one characteristic may be used to describe a waste, causing it to be counted more than once.

Many respondents described their waste under question 11 of the survey. This information was very helpful for filling data gaps in the remainder of the survey.

Table 12 is a summary total of the off-site waste composition as reported in question 12 of the survey. It is important to realize that the table does not list TPY of the component indicated. The table lists the TPY of waste that is described by the listed characteristic without regard to any other characteristic. Examples: 15,832 TPY of waste containing 10 to 30% organic, 6128 TPY of waste containing 1 to 10% sulfur, or 743 TPY of waste containing 1 to 10% fluorides. It was anticipated that respondents would check only the boxes considered significant. It was not surprising that many characteristics (rows) had no boxes checked and therefore appeared in the "Not Indicated" column. Most of the TPY "Not Indicated" would be expected to fall in the zero percent column. The TPY listed in the significant percentage ranges should be considered minimums. For instance, there are at least 635 TPY of waste that is 70 to 90% chlorine.

In response to question 13, the primary group reported 15,395 TPY acid and 14,048 TPY base. The secondary group reported 12,179 TPY acid and 5830 TPY base. The total "As Reported" was 27,574 TPY acid and 19,878 TPY base. The 5-year state-wide projection for the primary group is 9404 TPY acid and 37,231 TPY base, and for the secondary group 38,490 TPY acid and 6311 TPY base. The total 5-year state-wide projection is 47,894 acid and 43,542 base.

TABLE 10. OFF SITE WASTE DISPOSAL METHODS

	Respondants As Reported TPY		State-Wide 5 Yr Projection TPY		
	Primary Group	Secondary Group	Primary Group	Secondary Group*	Total
Destructive					
Chemical oxidation	0	10	30	0	30
Thermal treatment					
Incineration	6,980	1,622	35,054	7,499	42,553
Pyrolysis	3	0	1,643	0	1,643
Boiler fuel	6,476	382	3,218	470	3,688
Cement kiln	4,699	685	16,497	1,025	17,522
Not specified	2,079	0	26,372	0	26,372
Chemical treatment					
Neutralization	27,503	3,432	11,956	5,233	17,189
Precipitation	15,357	5,874	1,470	4,802	6,272
Reduction	0	25	0	30	30
Not specified	17,824	2,588	33,565	7,482	41,048
Physical treatment					
Adsorption	0	0	5	0	5
Carbon	2,984	1,577	4,394	4,194	8,588
Ion exchange resin	0	1,577	203	3,544	3,747
Not specified	19	0	0	0	0
Thermal separation				0	
Distillation	4	494	3,715	686	4,401
Evaporaton	0	0	2,450	0	2,450
Not specified	5,485	0	12,805	0	12,805
Solids separation					
Centrifugation	0	10	125	0	125
Filtration	1,372	4,679	72	19	91
Settling/clarification/ precipitation	18,878	1,001	8,879	0	8,879
Not specified	5,401	0	10,801	105	10,906
Liquid-liquid extraction	0	0	2,890	0	2,890
Land based treatment/disposal/ storage					
Landfill					
Sanitary(Munic.unreg.)	13,997	5,307	40,558	26,120	66,678
Hazardous(secure)	39,022	9,848	97,460	13,136	110,596
Land application	0	0	298	0	298
Land spraying(above ground)	0	0	0	3,371	3,371
Land farming(below ground)	0	0	28,194	0	28,194
Deepwell	14,000	0	4,763	0	4,763
Ponding					
Solar evaporation	0	0	891	0	891
Not specified	438	0	0	0	0
Resource recovery					
Solvent	3,932	944	16,182	2,115	18,297
Oil	138	479	861	6,260	7,121
Metals	0	3,064	0	13,574	13.574
Energy	1,314	22	10,351	185	10,536
Not specified	375	17	876	35	911
Storage off-site	459	0	1,554	0	1,554
Biochemical treatment	11,055	337	27,066	601	27,667
No method indicated	569	4,251	223,788	27,596	251,384

*Estimated to be 20% of total. See text p. 15.

Note: Wastes may be counted more than once if more than one disposal method is applicable.

TABLE 11. OFF-SITE WASTE CHARACTERISTICS

	Respondents As Reported TPY		State-Wide 5 Yr Projection TPY		
	Primary Group	Secondary Group	Primary Group	Secondary[a] Group	Total
General characteristics					
Inorganic					
Acid	10,496	8,546	4,945	19,804	24,749
Alkali	14,101	2,707	37,417	232	37,649
Metal sludges/slurries	2,715	2,068	8,530	5,525	14,055
Salts and brines	16,967	4,271	40,811	207	41,018
Metal finishing solutions (e.g., plating etching, pickling)	506	2,209	254	7,169	7,423
Catalysts	6,394	0	20,157	0	20,157
Flyash	44	0	225	0	225
Scrubber sludge	19,382	0	57,895	0	57,895
Water treatment sludge	2,465	1,141	9,099	2,786	11,885
Filter aids and clays	17,270	176	50,842	779	51,621
Construction debris	0	1	0	2	2
Tank clean-out residues	18	5,728	31	17,057	17,088
Off-spec chemicals	715	635	3,216	1,386	4,602
Returned goods	18	3	35	6	41
Contaminated soils and sediments	2,187	825	3,907	3,537	7,444
Contaminated in solution	6,954	334	7,798	1	7,799
Other	26,744	8,920	47,057	37,078	84,135
Organic					
Used oil/oily sludges	10,304	433	51,312	1,287	52,599
Spend solvents	17,209	2,036	58,252	4,944	63,196
Contaminated spill cleanup	5,375	0	2,644	0	2,644
Biological sludges	46,594	1,000	143,067	3,371	146,438
Sludge/slurry	37,362	2,097	134,639	5,528	140,167

TABLE 11. (CONTINUED)

	Respondents As Reported TPY		State-Wide 5 Yr Projection TPY		
	Primary Group	Secondary Group	Primary Group	Secondary[a] Group	Total
Organic (Continued)					
Still bottom residue	15,785	176	70,378	807	71,185
Spent carbon	536	379	2,177	1,335	3,512
Tank clean-out residues	4,256	417	17,081	1,268	18,349
Metallo-organic	2,813	0	7,227	0	7,227
Trash (paper, wood, plastic, metal, rubble, etc.)	77	119	293	325	618
Contaminated trash (included as organic solids)	238	66	428	184	612
Lab waste (samples, reagents, etc.)	660	1,506	1,948	3,282	5,230
Solid plastics, rubber	627	2,060	1,469	9,934	11,403
Contaminated soils/ sediment	5,069	8	664	37	701
Lagoon sludge/sediments	1,022	0	1,043	0	1,043
Off-spec chemicals	4,035	217	17,422	839	18,261
Returned goods	1,186	0	6,272	0	6,272
Not indicated	233	4,320	1,029	20,253	21,282
Specific characteristics					
Cyanides	94	601	250	1,247	1,497
Sulfides	16,525	0	31,522	0	31,522
Trace organic	16,919	2,127	48,291	5,198	53,489
Trace inorganic	32,925	2,739	89,587	6,722	96,309
Aqueous	53,481	16,679	115,621	42,740	158,361
Chlorinated organics	14,121	859	52,685	1,961	54,646
Halogenated organics	4,383	1,385	20,391	3,072	23,463

TABLE 11. (CONTINUED)

	Respondents As Reported TPY		State-Wide 5 Yr Projection TPY		
	Primary Group	Secondary Group	Primary Group	Secondary[a] Group	Total
Specific characteristics (Continued)					
PCBs	21	2	35	8	43
Asbestos	69	3	184	7	191
Organic nitro groups	751	120	3,715	485	4,200
Organic sulfur	748	600	2,976	1,244	4,220
Metallo-organic (e.g., tetraethyl lead)	3,499	0	9,745	0	9,745
Polychlorinated biphenyls (PCBs) at >50 ppm	7	1	12	2	14
Vinyl chloride	0	210	0	1,069	1,069
Metals	29,741	14,957	119,623	28,042	147,665
Alkali metal salts (e.g., Na, K, Li)	3,658	4,267	12,537	226	12,763
Not indicated	25,304	10,803	62,335	45,194	107,529
Special handling characteristics					
Volatile (>1.5 psig at ambient conditions)	8,146	786	24,061	1,610	25,671
Flash point, <140°F	21,592	2,636	74,587	6,199	80,786
Pyrophoric	3	0	5	0	5
Explosive	3	0	5	0	5
Shock sensitive	3	0	5	0	5
Unstable peroxide	0	0	0	0	0
Odor - organic	21,638	261	83,071	1,117	84,188
Odor - inorganic	12,487	4,200	10,173	4	10,177
Corrosive	25,459	11,749	47,092	21,509	68,601
High viscosity	2,748	74	13,512	264	13,776

TABLE 11. (CONTINUED)

	Respondents As Reported TPY		State-Wide 5 Yr Projection TPY		
	Primary Group	Secondary Group	Primary Group	Secondary[a] Group	Total
Special handling characteristics (Continued)					
Suspended solid	44,338	7,253	152,180	8,987	161,167
Waste characteristics change during storage	98	53	856	214	1,070
Compatability problems	106	33	302	84	386
Large bulky waste	2,508	43	6,023	166	6,189
Pathological	130	0	295	0	295
Pumpable only when heated to less than 250°F	125	41	697	164	861
Abrasive	35	0	103	14	117
Reactive with:					
Alkali	1,170	1,730	4,052	4,734	8,786
Acid	12,939	5	16,970	23	16,993
Oxidizer	408	0	1,619	0	1,619
Water	9,176	200	913	546	1,459
Other	5	600	21	1,244	1,265
Not indicated	48,298	20,720	111,851	77,604	189,455

[a] Estimated to be 20% of total. See text p 15.

Note: If more than one characteristic was used to characterize a waste, it may be counted more than once.

TABLE 12. OFF-SITE WASTE COMPOSITION

	Weight Percent								
	0	0-1	1-10	10-30	30-50	50-70	70-90	>90	Not Indicated
Respondents as reported (TPY)									
Primary Group									
Organic	4,304	12,827	69,636	15,832	3,772	8,072	5,975	21,275	19,091
Inorganic	3,882	5,755	70,020	21,474	16,636	2,061	13,862	5,929	21,165
Water	9,423	2,737	10,951	12,650	6,179	21,990	52,906	25,819	18,129
Carbon	742	7,128	76,029	7,174	6,185	9,634	15,254	3,858	34,780
Chlorine	6,077	28,795	25,274	765	2,088	40	635	124	96,986
Other halogens	8,281	2,291	5,111	1,311		1,000			142,790
Sulfur	10,241	16,605	6,128	2					127,808
Nitrogen	10,784	26,507	40,600	112					82,781
Phosphorus	11,019	14,593	105	72					134,995
Other	903	26,836	5,541	2,773	200	37		11	124,483
Sodium chloride	6,724	5,067	28,408		2,350				118,235
Fluorides	24,757	20,314	743						115,152
Other salts	7,008	2,637	21,734	15,892	11,851	40			101,622
Heavy metal compounds[a]	21,268	3,613	18,988	786	72	3	18		116,036
Other	2,911	3,497	44,297	4,119	6,233	2080	13,866	3,033	80,748
Secondary group									
Organic	2,411	2,589	1,538	4,266	8,337	139	557	4,077	13,088
Inorganic	19	2,035	7,093	7,206	3,735	92	22	6,169	10,631
Water	234	412	207	3,366	161	5,566	11,252	4,191	11,613
Carbon	687	2,588	538	5,056	3,465	733	428	3,003	20,504
Chlorine	7,295	1,042	382	60	5	18		37	28,163
Other halogens	7,295	859		10				2	28,836
Sulfur	5,728	2,459	11						28,804
Nitrogen	2,295	5,979	360						28,368
Phosphorus	2,455	5,709							28,838
Other	1,606		89	195	3,120				31,992
Sodium Chloride	3,327	2,436	9,200	62					21,977
Fluorides	9,367	729	667						26,239
Other salts	2,640	3,131	10,209	3				144	20,875
Heavy metal compounds[a]	1,606	2,716	6,746	269	560	37	2	388	24,678
Other	1,799	220	698	1,634	3,169	5	6	3,632	23,839

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TABLE 12. OFF-SITE WASTE COMPOSITION (cont'd.)

	Weight Percent								
	0	0-1	1-10	10-30	30-50	50-70	70-90	>90	Not Indicated
State-wide 5 yr Projection (TPY) Primary Group									
Organic	11,405	37,093	178,831	52,706	8,021	18,521	23,885	81,593	34,461
Inorganic	10,080	14,674	214,140	69,721	45,948	4,124	1,115	14,547	72,167
Water	11,520	9,562	42,597	10,842	12,229	95,375	136,564	61,794	66,033
Carbon	2,973	22,820	215,568	11,282	19,745	25,207	57,250	13,092	78,579
Chlorine	16,605	91,878	41,785	2,249	10,568	104	3,091	488	279,748
Other halogens	21,590	5,764	5,107	4,018		4,763			405,274
Sulfur	24,636	64,958	22,025	8					334,889
Nitrogen	26,875	85,572	91,243	420					242,406
Phosphorus	28,269	55,290	447	321					362,189
Other	3,641	40,461	47,882	7,751	799	141	0	87	345,754
Sodium chloride	18,418	18,492	89,424		5,687				314,495
Fluorides	83,057	27,843	2,775						332,841
Other salts	17,550	9,923	62,972	47,591	30,863	78		1	277,538
Heavy metal compounds[a]	53,679	39,169	65,788	1,339	77		4	71	286,389
Other	6,591	37,525	113,446	15,506	19,696	4,192	1,136	8,025	240,399
Secondary group									
Organic	2,366	7,245	4,964	20,052	31,408	476	1,557	13,694	29,902
Inorganic	53	4,558	30,823	9,394	7,650	305	70	19,274	39,537
Water	943	926	523	6,778	589	26,132	28,831	10,939	36,003
Carbon	1,877	7,245	1,594	24,885	7,164	1,797	1,866	11,270	53,966
Chlorine	30,221	3,824	1,667	328	2	33	127		75,462
Other halogens	30,221	3,969		31			4		77,439
Sulfur	26,707	7,570	31						77,356
Nitrogen	5,508	29,175	700						76,281
Phosphorus	6,272	27,948							77,444
Other	3,626		295	350	6,079	1			101,313
Sodium Chloride	9,083	7,513	24,724	170					70,174
Fluorides	36,312	2,043	3,069						70,340
Other salts	7,206	9,410	27,343	6	4			583	67,112
Heavy metal compounds[a]	3,626	7,304	9,263	766	1,376	140	3	1,060	88,126
Other	3,970	599	2,323	4,463	6,220	20	19	11,493	82,557

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TABLE 12. (CONTINUED)

	Weight Percent								
	0	0-1	1-10	10-30	30-50	50-70	70-90	>90	Not Indicated
Total State-Wide 5 Yr Projection (TPY) Total									
Organic	13,771	44,338	183,795	72,758	39,429	18,997	25,442	95,287	64,363
Inorganic	10,133	19,232	244,963	79,115	53,598	4,429	1,185	33,821	111,704
Water	12,463	10,488	43,120	17,620	12,818	121,507	165,395	72,733	102,036
Carbon	4,850	30,065	217,162	36,167	26,909	27,004	59,116	24,362	132,545
Chlorine	46,826	95,702	43,452	2,577	10,570	137	3,218	488	355,210
Other halogens	51,811	9,733	5,107	4,049		4,763	4		482,713
Sulfur	51,343	72,528	22,056	8					412,245
Nitrogen	32,383	114,747	91,943	420					318,687
Phosphorus	34,541	83,238	447	321					439,633
Other	7,267	40,461	48,177	8,101	6,878	142	0	87	447,067
Sodium chloride	27,501	26,005	114,148	170	5,687				384,669
Fluorides	119,269	29,886	5,844						403,181
Other salts	24,756	19,333	90,315	47,597	30,867	78		584	344,650
Heavy metal compounds[a]	57,305	46,473	75,051	2,105	1,453	140	7	1,131	374,515
Other	10,561	38,124	115,769	19,969	25,916	4,212	1,155	19,518	322,956

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[a] Excluding aluminum and iron.

Table 13 is a summary total of used oil reported in question 14. These data may be useful when assessing the potential recovery of oil or potential fuel for boilers or incineration. Some respondents checked more than one used oil category. Therefore, double counting has caused the combined categories to exceed the total for all categories.

Table 14 is a summary total of off-site metal wastes reported in question 15. Question 16 addresses the metals present in the off-site wastes. Table 15 lists the metals that are reported to be in the waste and the TPY of waste that contain these metals. Table 16 is a summary total of the TPY that have the listed metal identified as a major metal in the waste. For many wastes more than one metal was listed, and the waste was listed under each metal. These data may be useful for assessing potential metal recovery or assessing the needs for stabilization/solidification and landfill.

Table 17 is a summary total of off-site wastes reported to have a potential for recovery of the solvents listed by question 17. The first row lists the total TPY of waste that has the potential for solvent recovery. For every solvent the TPY of waste is listed that contains greater than 10% of the indicated solvent. Some wastes contain more than one solvent with a concentration greater than 10% and are counted more than once.

Table 18 presents the results from questions 18 through 21. Each question was considered separately and the only wastes counted were those associated with responses to that question. Question 18 concerned the percent of dissolved solids in the indicated waste; question 19 concerned the ppm of total organic carbon (TOC); question 20 concerned the ppm of chemical oxygen demand (COD); and question 21 concerned the waste biochemical oxygen demand (BOD_5). The state-wide 5-year TPY projection is also presented assuming the same average concentrations. These data may be very useful for considerations of biodegradation treatment facilities. However, the responses to these questions were insufficient for a confident projection and it appears that many of the wastes listed as biodegradable are not reasonable candidates for a biotreatment facility.

Table 19 is a summary total of the off-site wastes with an assigned heat of combustion falling within the indicated range. These data were obtained from survey question 22. Many respondents did not provide a heat of combustion response. A heat of combustion estimate was made for each waste on the basis of other data supplied by the questionnaire. Question 11 was very important in the determination of the maximum heat content available for potential incineration considerations. It would not be practical to incinerate all waste. Several other factors must be taken into consideration to determine the potential waste considered as appropriate for incineration. These factors are covered in the summary and conclusions section.

Table 20 is a summary total of the off-site waste categorized as displaying high acute toxicity by survey question 23. Approximately one-

TABLE 13. OFF-SITE USED OIL WASTE

	Respondents As Reported TPY		State-Wide 5 Yr Projection TPY	
Primary group				
Used oil (any category)	8,951		49,191	
Used vehicle oil		189		419
Organically contaminated oil		1,283		3,969
Used industrial lubricating oil		514		576
Oily sludge		2,004		33,717
Other		5,444		10,992
Secondary group[a]				
Used oil (any category)	3,766		7,117	
Used vehicle oil		31		101
Organically contaminated oil		19		53
Used industrial lubricating oil		3,718		6,967
Oily sludge		3,564		6,486
Other		3,634		7,635
Combined				
Used oil (any category)	12,717		56,308	
Used vehicle oil		220		520
Organically contaminated oil		1,302		4,022
Used industrial lubricating oil		4,232		7,543
Oily sludge		5,568		40,203
Other		9,078		18,627

[a] Estimated to be 20% of total. See text p. 15.

TABLE 14. CATEGORIES OF OFF SITE-WASTE CONTAINING METALS

	Respondents As Reported TPY		State-Wide 5 Yr Projection TPY	
Primary group				
Metal wastes (any category)	2,969		7,564	
Single metal sludge		1,636		3,006
Mixed metal sludges		1,330		4,553
Single metal slag or dust		3		4
Mixed metal slags or dusts		3		5
Secondary group[a]				
Metal wastes (any category)	1,597		4,071	
Single metal sludge		140		390
Mixed metal sludges		1,228		3,057
Single metal slag or dust		229		623
Mixed metal slags or dusts		0		0
Combined				
Metal wastes (any category)	4,566		11,635	
Single metal sludge		1,776		3,396
Mixed metal sludges		2,558		7,610
Single metal slag or dust		232		627
Mixed metal slags or dusts		3		5

[a] Estimated 20% of overall total. See text p. 15.

TABLE 15. OFF-SITE WASTE CONTAINING METALS

Metals Contained	Respondents As Reported TPY Primary Group	Secondary Group	State-Wide 5 Yr Projection TPY Primary Group	Secondary Group[a]	Total
Beryllium	1	0	2	0	2
Silver	5,115	11,230	13,721	30,130	43,851
Selenium	456	1,406	2,370	3,515	5,885
Manganese	2,327	6,788	9,715	30,567	40,282
Cadmium	5,731	3,978	17,707	7,824	25,531
Zinc	22,052	14,169	72,055	37,575	109,630
Arsenic	3,975	784	11,244	3,541	14,785
Iron	29,212	15,107	92,706	42,316	135,022
Chromium	22,442	8,687	105,184	12,298	117,482
Antimony	785	0	1,725	0	1,725
Lead	7,497	9,599	52,779	34,313	87,092
Cobalt	2,083	6	8,345	15	8,360
Copper	19,549	11,893	69,879	33,762	103,641
Thallium	0	0	0	0	0
Magnesium	9,089	5,808	53,755	28,459	82,214
Aluminum	10,969	7,308	64,953	27,004	91,957
Nickel	19,130	7,098	73,251	9,827	83,078
Mercury	481	996	1,706	2,720	4,426
Barium	3,209	2,559	38,208	7,450	45,658
Tin	361	3,089	2,133	8,616	10,749

[a] Estimated 20% of overall total. See text p. 15.

Note: Wastes may be counted more than once if they contain more than one metal.

TABLE 16. OFF-SITE WASTE WITH MAJOR METAL CONTENT

Specified Major Metal	Respondents As Reported TPY Waste		State-Wide 5 Yr Projection TPY Waste		
	Primary Group	Secondary Group	Primary Group	Secondary Group[a]	Total
	0	0	0	0	0
Silver	0	0	0	0	0
Selenium	0	0	0	0	0
Manganese	0	556	0	1,367	1,367
Cadmium	6	363	23	707	730
Zinc	2,077	4,272	5,115	6,465	11,580
Arsenic	2,479	0	5,968	0	5,968
Iron	1,948	7,423	4,122	18,927	23,049
Chromium	241	2,589	1,372	7,898	9,270
Antimony	0	0	0	0	0
Lead	1,369	948	4,717	2,150	6,867
Cobalt	0	0	0	0	0
Copper	1,532	1,473	4,483	4,047	8,530
Thallium	0	0	0	0	0
Magnesium	0	470	0	1,240	1,240
Aluminum	88	1,570	248	0	248
Nickel	1,250	1,219	4,141	4,755	8,896
Mercury	83	0	269	0	269
Barium	194	365	1,449	709	2,158
Tin	0	0	0	1	1

[a] Estimated 20% of overall total. See text p. 15.

Note: Wastes may be counted more than once if they contain more than one metal.

TABLE 17. SOLVENT RECOVERY POTENTIAL

	Respondents As Reported TPY		State-Wide 5-year Projection TPY		
	Primary Group	Secondary Group	Primary Group	Secondary Group[a]	Total
Waste with solvent recovery potential	10,153	1,832	34,747	4,044	38,791
Solvent					
Xylene	2,682	673	9,054	1,166	10,220
Perchloroethylene	1,000	1	4,763	2	4,765
Trichloroethylene	1,015	51	4,810	144	4,954
Methanol	4,183	2	13,519	8	13,527
Methylene chloride	3,019	27	13,830	105	13,935
1,1,1-Trichloroethane	1,017	17	4,809	32	4,841
Toluene	4,926	743	18,253	1,533	19,786
Methyl ethyl ketone	2,235	418	7,238	866	8,104
Freons	1,381	11	6,239	16	6,255
Acetone	4,090	35	14,307	142	14,449
Methyl isobutyl ketone	2,392	433	9,061	960	10,021
Other	5,027	1,259	22,389	2,654	25,043

[a] Estimated 20% of overall total. See text p. 15.

Note: Wastes may be counted more than once if they contain more than one recoverable solvent.

TABLE 18. SELECTED WASTE PARAMETERS

	Respondents As Reported		State-Wide 5 Yr Projection	
	Average	TPY Waste	Average	TPY Waste
Primary group				
Dissolved solids content (%)	11.5	43,333	11.9	133,255
Total organic carbon (ppm)	30,112	3,565	30,112	12,714
Chemical oxygen demand (ppm)	23,141	48,012	23,141	152,145
Biodegradable waste		51,213		193,886
BOD_5 (ppm)	5,685	3,440	5,685	12,136
Secondary group[a]				
Dissolved solids content (%)	15.2	8,115	15.0	31,052
Total organic carbon (ppm)	7,551	5,630	7,551	23,760
Chemical oxygen demand (ppm)	27,750	5,858	27,750	24,263
Biodegradable waste		11,067		49,891
BOD_5 (ppm)	60,000	4,250	60,000	20,009
Combined				
Dissolved solids content (%)	12.5	51,448	12.8	164,307
Total organic carbon (ppm)	18,832	9,195	18,832	36,474
Chemical oxygen demand (ppm)	24,677	53,870	24,677	39,477
Biodegradable waste		62,279		243,777
BOD_5 (ppm)	16,548	7,690	16,548	32,145

[a] Estimated to be 20% of overall total. See text p. 15.

TABLE 19. HEAT OF COMBUSTION

Heat of Combustion Btu/lb	Respondents As Reported[a] TPY	State-Wide 5 Yr Projection TPY
Primary group		
<3,000	121,732	315,821
3,000 - 6,000	3,848	14,005
6,000 - 10,000	15,526	45,638
10,000- 15,000	16,032	63,475
15,000- 20,000	3,643	7,581
Total	160,781	446,520
Secondary group[b]		
<3,000	21,576	57,638
3,000 - 6,000	6,735	30,812
6,000 - 10,000	1,152	2,204
10,000- 15,000	542	1,879
15,000- 20,000	6,995	19,130
Total	37,000	111,663
Combined		
<3,000	143,308	373,459
3,000 - 6,000	10,583	44,817
6,000 - 10,000	16,678	47,842
10,000- 15,000	16,574	65,354
15,000- 20,000	10,638	26,711
Total	197,781	558,183

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[a] Includes heat of combustion values assigned by ITE.

[b] Estimated to be 20% of total. See text p. 15.

TABLE 20. TOXICITY

	Respondents As Reported TPY	State-Wide 5 Yr Projection TPY
Primary group		
Acute toxicity high by:		
Inhalation	14,328	23,990
Dermal	13,526	18,824
Ingestion	26,295	57,176
Not indicated as toxic	129,109	365,132
Secondary group[a]		
Acute toxicity high by:		
Inhalation	3,194	11,761
Dermal	2,283	5,872
Ingestion	8,853	13,854
Not indicated as toxic	25,020	85,625
Combined		
Acute toxicity high by:		
Inhalation	17,522	35,751
Dermal	15,809	24,696
Ingestion	35,148	71,030
Not indicated as toxic	154,129	450,757

[a] Estimated to be 20% of overall total. See text p. 15.

Note: Wastes may be counted more than once if they have high acute toxicity by more than one route.

third of the off-site waste was indicated to have high acute toxicity. Some wastes were indicated to have high acute toxicity by more than one route. These wastes were counted more than once.

Table 21 is a summary total of the off-site waste RCRA categorized as hazardous. Nearly half of the off-site waste was reported by question 24 to be classified as hazardous by RCRA. Some wastes were characterized as RCRA hazardous by more than one classification.

TABLE 21. RCRA HAZARDOUS WASTE

	Respondents As Reported TPY	State-Wide 5 Yr Projection TPY
Primary group		
Categorized as		
RCRA hazardous	77,804	218,371
Classified as:		
Ignitable	23,943	85,170
EP toxic	9,225	36,032
Corrosive	25,789	49,083
RCRA listed	13,635	34,390
Not indicated as RCRA hazardous	82,980	228,145
Total	160,784	446,516
Secondary group[a]		
Categorized as		
RCRA hazardous	13,541	24,980
Classified as:		
Ignitable	2,679	6,309
EP toxic	1,175	3,550
Corrosive	8,819	11,585
RCRA listed	2,659	7,659
Not indicated as RCRA hazardous	23,461	86,684
Total	37,002	111,664
Combined		
Categorized as		
RCRA hazardous	91,345	243,351
Classified as:		
Ignitable	26,622	91,479
EP toxic	10,400	39,582
Corrosive	34,608	60,668
RCRA listed	16,294	42,049
Not indicated as RCRA hazardous	106,441	314,829
Total	197,786	558,180

[a] Estimated to be 20% of overall total. See text p. 15.

SECTION 5

TREATMENT TECHNOLOGIES

In this section the currently available industrial waste treatment technologies and management practices are described and the relative cost effectiveness comparisons are presented for the waste treatment systems most commonly used. A broad range of technologies are available for treatment of industrial waste and many more are in the research or development stage. Table 22 lists the waste treatment technologies available, the applicable waste catagories that may be treated by each technology, and a measure of the degree of development for each technology.

Table 23 is a general comparison of the typical cost ranges for the treatment/disposal technologies currently practiced. The cost range is very broad for each treatment/disposal technology. The key cost influencing factors are footnoted for each technology. For many hazardous wastes the cheaper technology cannot satisfactorily treat the waste and the resulting disposal is not environmentally acceptable. In many cases proper treatment/disposal will require more than one technology.

Several treatment/disposal technologies are so capital-intensive that operating volume may be the greatest cost influencing factor. The cost is greatly impacted by the characteristics of the waste that may require special handling or additional materials. A practical narrow-range treatment/disposal cost comparison can be developed for categories of hazardous waste when the characteristics are well defined and the volumes specified. The primary objective of this study was to develop a projection of New Jersey industrial hazardous waste volume by categories that are characterized in the detail required to develop a practical treatment/disposal cost effectiveness comparison for the major treatment method.

Waste management technologies fall within four broad categories: source control, destructive treatment, disposal, and physical-chemical separations.

Source control describes waste management strategies that prevent waste from being generated or that segregate wastes for recycling. Pollution control at the source can take on the form of total recycling, elimination of by-products, or utilization of by-products that would otherwise constitute waste.

Destructive treatments destroy organic matter by converting it primarily to environmentally acceptable carbon dioxide, water, and ash. The techniques generally are not applicable to inorganic materials.

TABLE 22. APPLICATION OF HAZARDOUS WASTE MANAGEMENT TECHNOLOGIES

	Aqueous Inorganic	Aqueous Organic	Organic Liquid	Organic Solid	Inorganic Solid	Organic Sludge/ Slurry	Inorganic Sludge/ Slurry	Used Oil	Spent Solvent	Metal Waste	Facility Wastewater	Technology Development[a]
Biological oxidation												
Suspended growth		X									X	1
Attached growth		X									X	1
Anaerobic		X	X		X						X	1
Chemical oxidation												
Chlorine	X	X										1
Oxygen	X	X										1
Ozone	X	X										2
Hydrogen peroxide	X	X										2
UV catalyzed	X	X										2
Thermal destruction												
Single chamber liquid		X	X					X	X			1
Rotary kiln		X	X	X		X		X	X			1
Multiple hearth		X	X	X		X		X	X			1
Fluid bed		X	X			X		X	X			2
High temperature chlorinated/organic		X	X					X	X			2
Pyrolysis		X	X	X		X		X	X			2
Molten salt combustor		X	X			X		X	X			3
Cement kilns			X	X		X		X	X			2
Coincineration/boilers			X					X	X			2
At-sea incineration		X	X	X		X		X	X			2
High temperature fluid wall		X	X					X	X			3
Plasma arc torch		X	X					X	X			3
Magnetic furnace		X	X	X		X		X	X			3
Super critical water	X	X	X					X	X	X	X	3
Microwave		X	X	X		X		X	X			3

TABLE 22. APPLICATION OF HAZARDOUS WASTE MANAGEMENT TECHNOLOGIES (cont'd)

	Aqueous Inorganic	Aqueous Organic	Organic Liquid	Organic Solid	Inorganic Solid	Organic Sludge/ Slurry	Inorganic Sludge/ Slurry	Used Oil	Spent Solvent	Metal Waste	Facility Wastewater	Technology Development[a]
Disposal												
Natural waters	X	X									X	1
Deep well injection	X	X									X	1
Stabilization	X				X		X			X		2
Land farming		X	X	X		X						1
Secure landfill	X				X		X					1
Solar evaporation	X	X					X			X		1
Physico-chemical separations												
Emulsion breaking												1
Density differential separators		X	X					X	X			1
Filtration/coalescence		X	X					X	X			2
Chemical separation		X	X					X	X			2
Electrical separation		X	X					X	X			2
Thermal separation		X	X					X	X			
Volatilization												
Fractional distillation		X	X					X	X			1
Steam stripping		X	X					X	X			1
Evaporation		X	X					X	X			1
Inert-gas stripping		X	X					X	X			1
Adsorption												
Carbon nondestructive regeneration		X									X	2
Thermal regeneration		X									X	1
Synthetic										X		2
Extraction			X									1

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TABLE 22. APPLICATION OF HAZARDOUS WASTE MANAGEMENT TECHNOLOGIES (cont'd)

	Aqueous Inorganic	Aqueous Organic	Organic Liquid	Organic Solid	Inorganic Solid	Organic Sludge/ Slurry	Inorganic Sludge/ Slurry	Used Oil	Spent Solvent	Metal Waste	Facility Wastewater	Technology [a] Development
Liquids/solids separation												
Screening				X	X	X	X	X				1
Clarification/thickening						X	X			X		1
Dewatering				X	X	X	X			X		1
Pressure filtration				X	X	X	X			X		1
Vacuum filtration				X	X	X	X			X		1
Belt filtration				X	X	X	X			X		1
Centrifuge				X	X	X	X			X		1
Chemical precipitation/ neutralization	X		X							X	X	1
Membrane separation												
Dialysis	X											2
Reverse osmosis	X									X		2
Ultra filtration	X											2
Electrodialysis	X											2
Ion exchange	X									X		1
Source control												
Recycle/reuse	X	X	X	X	X	X	X	X	X	X	X	2

[a]
1 - Full scale common use.
2 - Moderate application.
3 - Research/commercialization stage.

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(PREVIOUSLY CIN EPA FORM 387)
TYPING GUIDE SHEET

TABLE 23. COMPARISON OF TYPICAL TREATMENT/DISPOSAL COSTS

Treatment/disposal	Cost (1982 $/ton)
Biological oxidation[a]	20 - 150
Chemical oxidation[b]	20 - 140
Incineration - general[c]	0 - 1000
Liquid	20 - 100
Rotary kiln	70 - 1000
Fluid bed	5 - 20
Cement kiln	0 - 100
High temperature chlorinated organics	300 - 1000
Disposal[d]	
Deep-well injection	10 - 90
Stabilization/solidification	85 - 180
Land farming	5 - 25
Secure landfill	20 - 375
Solar evaporation	20 - 30
Emulsion breaking[e]	50 - 180
Chemical precipitation/neutralization[e]	15 - 450
Carbon adsorption[f]	
Thermal regeneration	0.35 - 0.85 ($/1000 gal)
Nondestructive regeneration	0.43 - 0.51 ($/1000 gal)

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[a] Economics of biological treatment are influenced by waste and site specific conditions such as hydraulic loading, organic loading, and treatability.

[b] Chemical oxidation processes are capital intensive. Roughly 75% of the annual operating costs can be attributed to fixed costs related to the capital for the project.

[c] As indicated, costs for incineration can vary extensively depending on types, quantities, and relative hazards of the waste to be destroyed (PCBs are more expensive to destroy than used oils). The form of the wastes (solids and drums require more handling and equipment than bulk liquids and are therefore more expensive to dispose of), the type of incinerator (rotary kilns require more capital than single-chamber liquid incinerators), and the flue gas cleaning requirements (halogenated wastes often require wet scrubbing).

[d] Costs for disposal will depend on location and transportation, excavation, drilling, and material costs.

[e] Depends on method and chemical reagent costs.

[f] Adsorption costs are most affected by concentration of adsorbents in waste stream.

Disposal can be considered to be controlled, long-term storage on or under the land at a dedicated location. Disposal can also include discharge to natural receiving waters without damage to the environment.

Physical-chemical separations are processing techniques often used in conjunction with other treatment methods. They can be used as pretreatment before destruction or disposal or they can be used as resource recovery techniques to separate and recover valuable chemical components for reuse or resale or for recovery of energy values.

The following discussion on waste-management technologies is presented as a summary of the principles and applications of the technologies currently available for the destruction, disposal, and physical-chemical treatment of hazardous waste.

SOURCE CONTROL

The ideal solution is to reduce waste at the source by changing or adjusting the industrial processes so that hazardous by-products are not produced. Process equipment should be designed to provide for chemical reuse rather than once-through processing. If processes cannot be changed, safer substitutes should be introduced where possible for those products or processes that generate hazardous wastes. Source control requires imaginative review of processes within the framework of pollution control to determine if the way the product is presently manufactured is really the optimum when control and treatment of process effluents are taken into consideration.

This report does not address specific opportunities for waste reduction. Although major producers of hazardous wastes are re-examining their production processes to reduce waste generation, these activities tend to be specific to individual production processes. Based on presently available information, it is impossible to determine the extent to which source reduction will reduce the volume of wastes produced.

Waste Exchange

Waste exchanges are organizations that manage or arrange the transfer of materials between industries, so that one producer's waste material might be another industry's feedstock. Waste exchanges were started in the early 1970s in Europe. While some exchanges actually broker wastes (purchase and sell waste materials), most are best described as information clearinghouses which provide information on waste availability.

In most cases, the waste exchange provides lists of available wastes in some coded form to provide anonymity for the generator. Inquiries concerning these wastes are then forwarded to the generator, and any resulting transactions are the responsibility of the respective parties involved.

Today there are about 20 clearinghouses in this country. These exchanges are operated by industrial associations, chambers of commerce, universities, and state and local governments.

The EPA has announced that up to 3% of the total industrial waste has the potential for transfer and reuse. Some reports estimate the potential to be much higher, but high exchange volume in practice has not been realized.

Wastes with potential recycling value include:

- Wastes having high concentations of recoverable metals
- Solvents
- Alkalis
- Concentrated acids
- Catalysts
- Oils
- Combustibles (for fuel)

The exchange and reuse of waste materials reduces disposal costs and conserves raw materials including the energy required to process raw materials.

DESTRUCTIVE TREATMENT

Biological Treatment

Biological waste treatment is a generic term applied to a variety of processes that utilize active microorganisms to convert wastewater constituents to more stable forms. Biological processes generally employ high concentrations of active microorganisms, under controlled conditions, so that the decomposition rates of degradable organic and inorganic materials are vastly accelerated.

In biological treatment processes the wastewater is brought in contact with an active microbial population under favorable environmental conditions. When organic matter is aerobically decomposed by microorganisms, oxygen is consumed by the organisms and new cell mass is synthesized. The organisms also undergo progressive auto-oxidation of their cellular mass. Anaerobic microorganisms obtain their energy from organic compounds in the absence of oxygen.

In the design of industrial waste treatment facilities the reaction rate, the oxygen and nutrient requirements, and the quantity of sludge produced must be determined.

Biological waste treatment consists of controlling environmental factors to enable a culture of microorganisms to utilize the organic matter in the waste as a food source for reproduction (synthesis) and energy (assimilation). The rate of reaction is a function of temperature, pH, nutrient level, concentration of waste, and sludge composition.

The principal types of equipment used in a biological treatment system are an aeration tank to provide contact between the wastewater and the microorganisms, a solids-liquid separation device (such as a settling tank), sludge recycle pumps, and monitoring and control devices. Equipment for pH control, nutrient addition, solids handling, and final sludge treatment and disposal may also be required. Highly variable waste loads may necessitate the use of an equalization basin before treatment.

Aerobic biological treatment systems may be subdivided into suspended-growth and attached-growth processes. Suspended-growth processes utilize mixing mechanisms to suspend biological solids in a mixed liquor. Attached-growth processes involve the contact of waste with biological films that are attached to a support medium.

The conventional activated-sludge process is the most common example of an aerobic suspended-growth process and consists of the following steps:

- Primary sedimentation to remove settleable organic and inorganic solids
- Aeration of a mixture of waste and a biologically active sludge
- Separation of the biological sludge from its associated treated liquor by sedimentation
- Return of settled biological sludge to be admixed with the raw wastes

Activated-sludge systems can be classified as high-rate, conventional, or extended aeration processes, depending on the design loading factor or food-to-microorganism ratio (F/M), which is commonly expressed as the rate of organic loading per unit weight of biomass. Each process has advantages and disadvantages, and system selection often involves an economic balance between the relative costs of increased aeration tankage and solids handling facilities.

The biological decompostion of waste components that occurs in attached growth processes takes place in the biological slime layer that grows on the surface of a supporting medium. Historically, the most commonly applied aerobic fixed-film process has been the trickling filter, which is comprised of a cylindrical tank filled with graded media. Wastewater is applied to the surface through a series of rotating distributor arms, is allowed to pass through the bed, and then is collected at the bottom. Several process modifications have been applied to trickling filters, including multistage designs, recycle, and forced-draft aeration. Although its operational simplicity and low cost make the trickling filter a desirable system, its inability to consistently achieve the increasingly restrictive discharge limitations has limited its use in recent years. The rotational biological contactor and fluidized bed are alternate fixed-film biooxidation systems with advantages depending on the circumstances.

The historical application of anaerobic processes has been primarily for digestion of primary and waste-activated sludges. Anaerobic processes do not require oxygen and they generate methane, which is sometimes recovered for use as a fuel.

Biological treatment has been widely used in the treatment of aqueous organic wastes but has fundamental limitations. The biodegradability of organic compounds has been shown to vary widely among different chemical structures. The biodegradability of a compound depends on its molecular structure, the size and solubility of the molecule, the presence of more than one function group in the molecule, the type of biological organisms, the environmental conditions, the stream, the concentration of the particular constituent in the waste, and the effects of acclimation.

Current areas of development for biological treatment include specialized bacteria and genetic engineering. Specialized bacteria, commercially available at present, are able to degrade oils, aromatic hydrocarbon phenols, chlorinated phenols, and other organic hazardous wastes.

Chemical Oxidation

Chemical oxidation is used to chemically modify waste streams either by complete oxidation of the organic to carbon dioxide and water or by partial oxidation of the organics to detoxify them. These waste streams are usually aqueous wastes that cannot be handled directly by biological oxidation (either because of organic strength or bioinhibitory characteristics) or by incineration (because the organic concentration is too low or there is excessive corrosion caused by the presence of inorganic salts or halogens). Oxidation is also used to purify aqueous streams (such as waste sodium chloride brines) to permit recycling.

Most of the chemical oxidation processes are based on one of two oxidizing agents -- chlorine or oxygen. Many oxidation processes have been developed to modify the ability of these oxidizing agents to accomplish specific goals, usually by adjusting the stoichiometry and/or kinetics of the chemical reactions.

For most industrial wastes, chemical oxidation is most effectively applied on individual waste streams rather than on a mixture of wastes. This approach minimizes the compromises that might be required in dealing with a mixture of compounds with different optimum oxidation conditions.

The operating conditions in many chemical oxidation processes, particularly at elevated temperatures, are among the most corrosive known. Proper selection of materials of construction is crucial to ensuring continuous, long-term operation to achieve the desired removal. Expensive metals are often required to successfully contain oxidation reactions.

Because of the varying optimum conditions for the effluent chemical reactions, no one chemical oxidation process can be considered to be omnivorous. The ones that come closest to being omnivorous (catalyzed and uncatalyzed wet oxidation) are the most expensive. The capital costs for chemical oxidation processes are intensive. Roughly 75% of the annual operating costs are fixed costs related to the capital for the project, usually because of the expensive materials of construction required.

Of the oxidation technologies, only wet oxidation (catalyzed and uncatalyzed) and chlorinolysis are cost effective in dealing with wastes that contain greater than ~1% organics. Unless the waste volumes are small, the costs for the other oxidizing agents are so high that other ways of reducing the organic loading or the use of other oxidation techniques is usually more cost effective.

Chlorine--

A chlorine-dissolving system, a reactor, a scrubber to control emissions of chlorine, and a dechlorinator to remove the dissolved chlorine from the effluent are the major features that may be included in chlorination systems. For small chlorine usage the dissolving step is often eliminated by the use of bleach (sodium hypochlorite). Chlorine has long been used for oxidation reactions. It is readily available in 1-ton cylinders and 30- and 55-ton tank cars.

Variables that may be important are the temperature, the chlorine concentration, the presence of inhibitors, and the use of catalysts that improve the rate of reaction or favor the desired reaction when competing reactions are possible. One catalyst that is used to modify chlorination processes is ultraviolet (UV) light.

Chlorination can be used to destroy cyanide ions in wastewaters but control of pH is important. Chlorination can also be used to treat many metal cyanide complexes in wastewaters from metal treating and electroplating operations, with the notable exception of the highly stable cyanide complexes of iron and nickel.

One drawback to the use of chlorine is the production of potentially toxic by-products. In specialized cases, oxidizing agents other than chlorine, such as chlorine dioxide and bromine chloride, are used. The advantage of bromine chloride over chlorine is that it hydrolyzes in water to hypobromous acid and hydrochloric acid. Treatment of wastewaters containing ammonia or amines with bromine chloride prevents formation of chloramines, which are toxic to fish. A chlorination system can be easily converted to accommodate other reagents.

Oxygen --

The main oxidizing agents in this group are oxygen, ozone, and hydrogen peroxide. Oxygen (or air) is not effective in oxidizing many organics in wastewater and is rarely used alone. It usually needs to be activated by elevated temperature and pressure in wet oxidation and catalyzed wet oxidation processes or by converting it to ozone or hydrogen peroxide.

Wet oxidation, as in the Zimpro® process, has been developed in an effort to economically use oxygen or air to oxidize organic wastes. Such processes use a great amount of energy because they have to operate at 200 to 300°C and 1000 to 5000 psig to achieve the desired conversion. Capital costs are high because of the high pressure reactor design, the special materials of construction, and the energy recovery equipment required. Catalyzed wet-oxidation systems are being developed in an effort to reduce the temperature and pressure requirements. In spite of their high costs wet-oxidation processes have commercial value because they are often the only successful processes.

Wet-oxidation or catalyzed wet-oxidation processes can be used on dilute wastes or on concentrated wastes even above 1% organics. At process conditions concentrated wastes above ~2% organic are actually an advantage because all the energy requirements are supplied by the waste. In fact, some applications use steam generation to help offset costs. With the proper materials of construction, these processes can handle wastes with low pHs, inorganic salts, or free halogens. In some applications this may give the wet-oxidation processes an advantage over incineration.

Ozone is the most powerful oxidizing agent but is also the most expensive. It is generated from air or oxygen by an electric arc. It has a low solubility in water and a half-life of several minutes, which dictates that it be generated on site. The equipment has relatively high capital costs. Except for the ozone generator, a process for an ozone system is the same as for a chlorination system. Like chlorine, the potential of ozone as an oxidizing agent can be increased by UV light. For example, iron cyanide complexes, which are resistant to both alkaline chlorination and ozonation, can be decomposed by UV-ozonation. "Nitrobodies" in "pink water" from TNT manufacture and materials such as DDT and PCBs can also be degraded with UV-ozonation.

The technology for using ozone is for the most part developed. Commercial equipment to generate ozone is available, but until recently the high initial capital cost has discouraged its use on a large scale. Concern for the chlorinated organic by-products and/or for dissolved solids has led to the increased use of ozone.

Thermal Destruction

Incineration, or thermal destruction, is an effective method of destroying organic liquids, sludges, and solids and can be used for a relatively broad waste profile, depending on the type of incineration system utilized. Aqueous wastes can be handled if there is enough heat value in the organic portion of the wastes, or if auxiliary fuels are used to evaporate the water and combust the organic contaminant.

Incineration is generally defined as a controlled, high-temperature oxidation reaction between combustible substances and air or oxygen, under controlled conditions of retention time, temperature, and turbulence within a dedicated single or multiple combustion chamber of the proper geometric configuration and size. The end products of the combustion reaction are carbon dioxide (CO_2) and water (H_2O) from hydrocarbon wastes; but hydrogen chloride (HCl), sulfur dioxide (SO_2), and less desirable combustion by-products may also be generated, depending on the nature of the wastes, the operating features of the specific incineration system, and the compatibility of the waste profile and incineration system.

Better than 99.99% destruction of organics can be achieved under controlled combustion conditions. The most important operation parameters are the combustion temperature and the retention time of the gaseous products within the system. Recent RCRA criteria specify a destruction and removal efficiency (DRE) of 99.99% for general hazardous wastes and 1200°C for 2 sec for halogenated aromatic hydrocarbon liquids. Another significant parameter is the amount of excess air introduced during the thermal oxidation process, "excess air" being the amount of air in excess of that needed to supply the stoichiometric quantity of oxygen for the complete oxidation of all organic materials and fuels being incinerated. In a vapor stream 20% excess air may be adequate; but with atomized liquids, aerosols, and organic particulates, excess air levels of 50 to 100% are appropriate. For destruction of solids, agitation and mixing are also important.

Although incineration has been used for a long time, its acceptability has been limited by its relatively high capital and operating costs compared with those of landfill operations. In addition, for industrial waste incineration the complexity of feeding a variety of waste materials makes the design requirements of each system relatively unique. Well-trained operating personnel and effective instrumentation are necessary for the proper operation of large industrial incineration systems handling hazardous materials. Feed handling and blending should be well designed to minimize thermal shocks and upsets to the system. Solids shredding systems can be used, but they tend to be high-maintenance items. Exotic alloys may be required for air pollution control equipment. Close attention to proper specifications of materials of construction can substantially reduce maintenance costs and improve system reliability.

Wastes containing arsenic (As) and selenium (Se) as well as other high-volatility metals should not be incinerated since the volatile oxides of these materials will pass through most gas scrubbing systems and be emitted to the atmosphere. Wastes containing other heavy metals should be avoided unless scrubbing systems and ash disposal methods are specifically designed to handle them. The heavy metals may be more difficult to remove or control from scrubbing stream purges than from the original waste stream, plus some will probably have been released to the atmosphere.

High levels of salts may create slagging, fouling, and corrosion problems within the combustion chamber and gas cleaning sections. These salts could generate fine particulates that may be difficult to remove without high-energy scrubbing. Organic wastes containing high levels of salts should be diluted with other wastes, or alternative treatment methods should be considered.

In order to minimize the formation of free chlorine in the flue gases from a multipurpose unit, organic chlorine levels in wastes should be controlled to 30% or less by dilution of highly chlorinated wastes with other wastes. Brominated organic wastes are a problem since the bromine-hydrogen bromide equilibrium is such that high levels of free bromine are emitted under oxidizing conditions. Brominated wastes should be avoided or burned separately in a system with appropriately designed combustion and gas cleaning systems. The blending of highly chlorinated and other hazardous wastes with nonhalogenated wastes is normally beneficial to the combustion efficiency of the hazardous components. Blending operations are important to large, general industrial waste incineration systems.

Many types of incinerators are manufactured, and each one is basically designed for specific waste profiles to meet emission regulations and other operating criteria. Most systems will handle liquids to some degree, but significant variations exist in sludge and solids handling capabilities. The internal operation of the combustion system can be static when solids agitation is not required, but most solids require agitation in order to continually expose fresh surfaces for rapid and complete oxidation. Only agitated systems are considered to be adequate for the combustion of solids that include hazardous components.

A single-chamber liquid incinerator can be used when only liquid wastes are to be destroyed. Liquids, sludges, and solids can be handled by mono- or multiple-hearth, fluidized-bed, and rotary-kiln incinerators, which are designed to provide bed agitation or turnover.

Waste handling and feed mechanisms, flue gas scrubbing, ash removal, and other related operations will vary with the characteristics and types of wastes to be incinerated. The following sections describe in more detail the various types of incinerators and associated equipment.

Single-Chamber Liquid Incinerator--

This type basically consists of a refractory-lined combustion chamber fired by one or more liquid-burner nozzles. Combustion air is usually added through the burner nozzles; secondary or tempering air can be introduced around the burner. Numerous models are commercially available.

A wide range of liquid wastes may be incinerated, provided the heating value is sufficient to maintain proper temperature and flame stability. When a low-heat-value liquid is incinerated, either it must be blended with a liquid of higher heat value or auxiliary fuel must be used. The liquid material must be atomized through a burner nozzle by air, steam, or mechanical means, although air or steam atomization is preferred. The absence of secondary combustion makes solids an unacceptable feed to this type of unit.

Tars and other viscous materials may have to be blended, heated, or kept hot in order to feed them through an atomizing nozzle. Since a significant amount of ash in the form of submicron inorganic salts or metal oxide particulates will be carried out of the combustion chamber with the flue gas, some degree of flue-gas cleaning will be necessary (except when liquids are of clean fuel quality). A certain amount of heavier inorganic particulate will drop out within the incinerator, and occasional shutdown and cleanout of the combustion chamber will be necessary.

Rotary-Kiln Incinerator--

Rotary-kiln incinerators are used as primary combustion chambers for solid and liquid wastes through a combination of thermal oxidation, pyrolysis, and vaporization. Combustion of the volatilized compounds is completed in a secondary combustion chamber. This design provides sufficient tumbling and turnover of the solid wastes to achieve complete burnout, and can accommodate liquids, sludges, combustible solids, and contaminated noncombustible solids. It has no internal moving parts, such as rabble arms, grates, or plows. Ash removal from the kiln is continuous, and the feed can be continuous and/or semi-continuous.

Depending on its diameter, feed mechanism, and ash removal system, a rotary kiln can accept waste containers as large as pallets or 55-gal drums. It is desirable to concurrently fire incinerable liquids atomized through a burner nozzle with the solid materials in the kiln to promote combustion and ultimate high-efficiency destruction of the solids.

Solid materials are fed into the kiln at a controlled rate through a feed shute or a ram charging mechanism. Solids are heated primarily by the burning atomized liquid materials. Burning proceeds rapidly at the center of the kiln, with burnout occurring in about the latter one-third of its length. Although a degree of pyrolysis occurs within the bed of burning solids, the nonvolatile pyrolytic products are destroyed during the burnout and the volatile pyrolytic and evaporated materials are destroyed in the secondary combustion chamber. Appropriate emission controls are necessary when particulates and acid gases must be removed from the products of combustion.

Multiple-Hearth Incinerator--

This type of incinerator utilizes mechanical agitation, which is provided either by a refractory-lined hearth or by air-cooled rabble arms being rotated slowly while the incinerable materials are fed along the periphery of the hearth. In a multiple-hearth unit the feed materials heat up, dry, ignite, and burn down during their spiral travel across and down a series of drying, burning, burnout, and cooling hearths. The solid material is turned over to expose fresh surface during its travel, and it is conveyed in opposite directions on consecutive hearths. The exit gases from a multiple-hearth unit leave below combustion temperatures as a result of the heat recovery and drying that take place on the upper hearths. Since a multiple-hearth unit has more hearth area than a single-hearth unit of equal diameter, its incineration capacity is greater.

Multiple hearths are commonly used for regenerating activated carbon or incinerating aqueous sludges, including dewatered biological sludges from wastewater treatment systems, because of heat economy in drying the solids. If the sludge is a wet chemical sludge, organic compounds may be volatilized from the top hearths into the exhausted flue gas, thus requiring secondary combustion of the flue gases.

Multiple-hearth designs are useful only for homogeneous sludges or solids, since large solids, wire, cloth, and sticky or slagging materials could plug or build up on the conveying rabble arms. These materials must be excluded or shredded to prevent the incinerator from being plugged. The incinerator usually requires preheating by liquid fuels and may require auxiliary fuel, fired through tangentially mounted burners located at one or more hearths, if the heat content of the solid material is not adequate to sustain combustion.

Fluid-Bed Incinerator--

Fluid-bed designs have been applied industrially to incinerate liquids, sludges, and relatively homogeneous solids that are produced within a narrow chemical profile. They offer the advantage of maintaining stable combustion over a broad aqueous concentration range since the bed media provides a significant heat sink. Intimate mixing of waste and combustion air occurs since the combustion air is also used for fluidization of the bed. As a result, very effective heat transfer and good burnout occurs with a minimum of excess air. Secondary combustion is usually not necessary. The most serious disadvantage of the fluid bed is potential fusion of the bed material caused by low-melting-point salts and ash. Also, as with multiple-hearth units, size reduction of solids is often required.

Chlorinated Organic Waste Incinerators--

Special incinerators, usually consisting of vortex-type burners firing downward into a quenching chamber or quench fluid (dilute acid, water, $CaCl_2$ solution), are used for the thermal destruction of highly chlorinated organic wastes with chlorine contents of 70% and greater. For wastes containing more than 70% chlorine it is necessary to add auxiliary fuel.

The combustion involves the chemical and thermal equilibrium among hydrogen chloride, chloride, water, and oxygen as follows:

$$H_2O + Cl_2 \rightleftarrows 2HCl + 1/2O_2$$

The essential principle of the incineration is to displace the combustion equilibrium to the right in order to favor the production of hydrogen chloride over chlorine.

To minimize the formation of chlorine, the incinerators are operated at conditions that assure a high temperature of combustion (about 1200°C) with essentially a theoretical amount of air, an optimum residence time, a water balance by steam and water injection or water quench, and an efficient quenching stage.

The hydrogen chloride in the combustion gases is recovered by absorption in water to produce hydrochloric acid. Depending on the ultimate use of the recovered hydrogen chloride, the incineration process will be operated either to neutralize the acid or to produce concentrated or gaseous hydrogen chloride for sale.

Pyrolysis--

The system as described by a vendor includes three components in sequence: a rotary hearth furnace, a rich fume reactor, and a heat recovery device. Waste is fed onto the rotary hearth and held at 540 to 760°F for 15 to 30 minutes depending on the type of waste. As the waste is volatilized, the gaseous fraction is passed to the reactor and is combusted to complete the destruction of hazardous compounds. The reactor is reported to operate at temperatures in the range of 1800 to 3000°F depending on the toxicity of gaseous components. Following combustion in the reactor, the gaseous fraction is released to a boiler for the extraction of heat energy.

The pyrolytic incineration process operates under quiescent atmosphere, so particulate carryover is claimed to be lower than for the conventional incineration process. Inorganic chemical constituents containing sulfur, phosphorus, and halides may be retained in the char because of lower pyrolysis temperature. Scrubbing equipment can be added, if need arises, to remove chemical pollutants such as SO_2, HCl, or P_2O_5 to meet emission standards. The process is commercially available.

Molten-Salt Combustion--

A molten-salt incinerator consists of a cylinder containing sodium carbonate and sodium sulfate which is maintained at a temprature of from 800 to 1000°C to keep the mix in a molten state. Liquid, solid, or gaseous wastes are injected beneath the molten salt and are combusted upon contact with the hot molten bath. Once the process begins, the heat of combustion of the various wastes being burned makes it self-supporting. Most of the ash and virtually all of the acidic products of combustion are retained in the molten bed rather than emitted to the atmosphere. The salt in the melt must be gradually replaced as ash contaminant rises.

The process is applicable to many waste types including pesticides, combustible industrial wastes, and hazardous chemicals including various carcinogens and low-level, radioactive wastes.

The advantages of the molten salt systems are:

- Compact units make it possible to design a portable unit
- Combustion takes place at lower temperatures than in conventional units, which saves energy and reduces maintenance costs
- Some products of combustion are retained in the melt, which reduces the need for air pollution control devices

The limitations of the unit are:

- Ineffectiveness in treating high ash wastes
- Temperatures which may not be high enough to completely combust some wastes
- Potential problems with continuous regeneration of the molten salts

Rockwell International has operated a pilot-scale molten salt unit capable of combusting up to 200 lb per hour of a variety of wastes. This unit, with its rather small capacity, is the only known example of molten salt combustion of hazardous wastes. Before this technology can be endorsed as an alternative treatment technology for hazardous waste, more demonstrations must be carried out with a commercial-scale system.

Cement Kilns--

An integral part of the process for manufacturing cement is exposing limestone and several additives to temperatures above 1400°C in a large rotary kiln fueled with a fossil fuel. The end product of this process is a solid material called clinker. Ground-up clinker is the major constituent of cement. Since the combustion conditions in cement production are much more severe than those present in many waste incinerators, cement kilns are considered to be a promising disposal option for many organic wastes. They are considered especially applicable for incinerating chlorinated wastes since the hydrochloric acid produced is neutralized by the clinker production process which is normally alkaline.

In test burns carried out in Canada, Sweden, and the United States, it has been determined that hard-to-burn wastes such as PCBs can be successfully combusted in cement kilns. Less hazardous chemicals such as waste solvents and still bottoms from solvent reclaiming operations are already being purchased by cement companies and burned as fuel on a continuous basis in cement kilns. The EPA is presently sponsoring a demonstration in Dorado, Puerto Rico using chemical waste as fuel in cement kilns.

The capacity of the cement industry to consume chemical wastes as fuel is quite large, and cement plants are already located near many waste-generating sources. The disadvantages are that burning chlorinated wastes in cement kilns appears to increase the production of particulates, requiring more extensive air pollution control devices, and utilizing wastes as fuel in plants will require an upgrading of the facilities. The EPA has estimated that enough cement-making capacity exists within the largest waste-producing states to incinerate all of the chlorinated wastes produced in those states. The California Air Resources Board recently recommended the use of cement kilns as a means of destroying PCB wastes.

Coincineration/Boilers--

The term "coincineration" describes the use of combustible wastes as supplemental fuels in boilers designed for and operated primarily on a fossil fuel. As a result of coincineration, the energy value of the waste is recovered and the waste is destroyed through combustion. Rather than requiring a unique technology, this incineration process can be carried out in any boiler where feed and combustion parameters make it possible.

The advantages of coincineration are: (a) capital expenditures are minimal, if present boilers can be modified to accept the wastes; and (b) wastes used as fuel on site need not be transported on the highways. Disadvantages are: (a) the introduction of some wastes into boilers designed to burn other fuels may be very harmful to the boilers; and (b) the difficulty of completely burning combined wastes of different heating values.

The question of the environmental impact of using boilers to burn wastes is unresolved. On one hand, combustion conditions in most industrial boilers are sufficient to burn most organic wastes. On the other hand, there are many hard-to-burn hazardous wastes that should not be put in boilers. The EPA has initiated a study to provide some guidance on the question because many boilers do not have sufficient air pollution control devices for the organics emitted.

Ocean Incineration--

Shipboard incineration uses the same technology as shore liquid waste incinerations without gas cleaning systems. Highly toxic wastes are incinerated at locations in the open sea away from populated areas and shipping lanes. Proponents claim that the necessity for the removal of acidic gas from the emissions is eliminated since the gases can be dispersed over the ocean without measurable effects to people or sea life.

Three ocean burnings of large amounts of toxic organochlorine wastes on a commercial incinerator ship, the M/T Vulcanus, have been carried out since 1974. The latest of these burns included the highly toxic herbicide, Agent Orange. The wastes were combusted at temperatures of up to 1500°C at a rate of 14.5 metric tons per hour.

The primary advantage of ocean incineration is that it takes place away from populated areas and may not require gas cleaning. The main disadvantage is the necessity for operating on-shore facilities for handling, storage, and loading the relatively large volumes of waste retained for an ocean-going incineration vessel.

High-Temperature Fluid Wall--

In this process, either liquid or granular solid wastes are pyrolized through application of radiant heat at 2200°F. The process is carried out in a patented reactor which consists of a tubular core of refractory material capable of emitting radiant energy supplied by large electrodes in the jacket of the vessel. During the process, an inert gas is injected to coat the wall of the reactor and prevent destruction from the high temperatures.

The manufacturer of the high temperature fluid wall claims that the unit can successfully destroy many types of hazardous waste. Theoretical calculations support this claim. To date, however, the reactor, which has been used primarily in chemical processes to produce various organic chemicals, has not been tested on hazardous chemicals. Pilot-scale facilities have been constructed and plans are being developed to carry out waste destruction tests.

Plasma Arc Torch--

In this patented process either solid or liquid wastes are pyrolyzed into combustible gases by exposing them to a gas which has been energized to its plasma state by an electrical discharge. The plasma gas, which can be at a temperature of 50,000°C, is extremely destructive to the molecular makeup of the waste. The off gases from the pyrolysis may have a fuel value of 400 Btu/ft^3. A scrubbing device would be needed to remove halogens and other off gases before the off gas could be used as a fuel.

The advantages claimed for this process are: (a) due to the high temperatures involved, there are no hazardous interim combustion products formed, (b) the process is very compact and could be made to be portable, and (c) the process is energy-efficient. The process has been proven in the laboratory and offers considerable promise as a waste destruction option. It is now in the initial stages of commercial development. Cost estimates are not available at this time.

Magnetic Furnace--

This method of incineration uses an iron core heated by an electrical induction coil. The iron is used to transfer energy as heat to waste and silica materials. The silica melts, and heavy metals and other inorganics lock on to the silica to form a black "sterile" slag that can be landfilled. The organics are pyrolyzed and vaporized and pass into an oxidizer unit which operates at temperatures up to 2200°C. The exhaust is cooled, then passed through a bag house and carbon filter before being released. The system has the capability of recovering Cl_2 gas for use or sale.

The unit is portable and can process up to 6000 lb/hr of PCB-contaminated soil.

Supercritical Water--

Based on using supercritical water, this thermal treatment process converts organic components to carbon dioxide and water and separates inorganic compounds for disposal or reuse.

A feed slurry of waste and water is heated to 400°C by the addition of supercritical water, obtained initially by startup heating and thereafter by the heat of oxidation in the reactor. Pressurized air or oxygen is added to the feed. Oxygen and many organics are highly soluble in water above the critical condition of 374°C and 3200 psi, a point at which liquid and vapor have the same density and are indistinguishable.

This feed stream is pumped to a heat-sealed reactor where the organics in the stream are oxidized at temperatures of 550°C or higher. Part of this superheated effluent is recycled to bring the newly entering waste and water to the supercritical state. The remaining high pressure can be vented or condensed. Larger systems can provide enough steam to generate power for the feed pumps and the oxidant-pressurizing pumps. Inorganics are removed in a cyclone-type salt separator.

Microwave--

This system uses a reactor tube or container through which the toxic material is passed. Microwaves are applied to the tube, inducing a plasma (ionized gas). The resulting electrical-chemical interaction instantly begins the decompostion process of the toxic material.

This process has been demonstrated on phenyl mercuric acetate, PCBs, malathion, and kepone with destructions of 99 to 99.9999%.

Emission Control--

When industrial and hazardous wastes are being incinerated, the flue gases should pass through a gas cleaning system in order to provide a safeguard against release of vaporized feed materials or thermal degradation products and to remove salt and oxide particulates and acid gases. However, gas cleaning systems are not substitutes that can overcome poor combustion or operating practices.

Regulatory codes will differ on both the controlled specific emission components, such as particulates and SO_2, and the allowable levels of each component. As regulations change, flue gas cleaning systems in particular must be given careful design consideration.

Particulates and acid gases are commonly removed by venturi or packed-tower scrubbers, although new scrubbing systems, such as wet electrostatic precipitators and high-efficiency air filters, are being developed and applied. Of specific concern is the removal efficiency needed for meeting particulate and other emission control requirements. The capability of any emission control system will depend on the nature of the components to be removed and on the system's specific design and type, energy input, and flue-gas preconditioning through controlled cooling. For example, a venturi scrubber operating at 20- to 30-in. w.c. pressure differential may adequately control particulate emissions from general municipal refuse, whereas a 60- to 70-in. w.c. pressure differential may be necessary for controlling particulates generated from liquids, sludges, or solids containing phosphorous or salts that tend to form fine submicron particulates.

Packed scrubbing towers commonly use pH-controlled scrubbing water to remove acid gases, halogens, or other materials. Scrubbing towers are generally not highly efficient as devices for removing particulates generated from industrial wastes.

Fabric filters, dry electrostatic precipitators, and cyclones can remove only particulate matter and not acid vapors or other gases. The use of these devices for cleaning incinerator flue gases is generally limited to removing particulates that are not highly deliquescent and that are solids at the normal operating temperature of these devices. Condensed liquid aerosols or deliquescent materials will build up, corrode the equipment, and be very difficult to remove from the collection equipment.

Wet scrubbing systems for removing acid gases, salts, and other constituents from the combustion gases will generate scrubbing liquor that must be purged from the system. The streams may be high in salts, especially when alkalis are used to remove or neutralize dissolved acid gases. Generally these streams are recycled until inorganic concentrations are built up to a predetermined level and then disposed of by a purge stream.

The ash generated by incineration normally is disposed of in landfills. The ash may contain various salts, heavy metals, and other potentially leachable materials that could be detrimental if care is not taken to use appropriate secured landfill procedures. The ash should be monitored to ascertain that the combustion process was complete and that no hazardous organic materials remain.

Energy Recovery--

The recovery of energy from the incineration of industrial wastes has not been widespread. Although the chemical industry has successfully recovered energy from selected waste streams, it generally has had little experience in recovering energy from the incineration of a mixture of wastes. The technology involved in this type of energy recovery must still be regarded as being in the development stage. The decision to incorporate energy recovery must be based on a careful consideration of the complications and the potential operating time loss that might occur as the result of failure of the energy recovery system.

There are several potential alternatives for the recovery of energy from waste incineration. The concentration or evaporation of a process liquid by direct contact involves minimum operating problems and the lowest operating cost. Contamination of the liquid that is being concentrated is a potential problem. The potential may also exist for the generation of inorganic submicron solid particulates, which could cause flue gas cleaning problems.

Low-level energy recovery can be accomplished by use of the flue gas to generate hot water or hot air. Using the flue gas heat to preheat combustion air may reduce auxiliary fuel requirements. This technology is reasonably well documented and involves less risk of failure than high-level energy recovery.

The generation of high-pressure steam is the most common example of high-level energy recovery. This form of energy recovery is generally the most desirable because of the many applications for the steam produced. To produce high-pressure steam for electricity generation requires such a high-temperature heat-transfer surface that the technical problems become more severe.

Several problems concerned with the recovery of energy from chemical waste incinerators are not significant problems in power generation with conventional fuel furnaces. Severe problems may be encountered concerning the corrosion due to slagging from inorganic salts such as chlorides, the corrosive action of HCl, the presence of SO_3 and P_2O_5, the presence of free halogens, the combined effects of slag, particulate, and HCl, and the steam energy level requirements. Secondary considerations include problems resulting from erosion, overly aggressive soot-blowing, effects of a variable oxidizing-reducing atmosphere, and variable steam generation, which creates temperature stresses in the boiler heat-transfer surface.

The most workable approach to energy recovery is to design a total facility with flexibility to allow segregation of specific problem chemicals from the energy recovery system.

DISPOSAL

Disposal into Natural Waters

The discharge of effluents into natural receiving waters is one of the oldest ultimate disposal methods for industrial wastes and has historically been a primary source of pollution in many rivers. However, the disposal of properly treated wastes into natural waters can be efficiently and effectively practiced without damage to the environment.

In the natural water ecosystem, microorganisms are present that utilize low levels of organic materials as a food source in their metabolic processes. Under normal circumstances this organic material is converted by aerobic biological processes to carbon dioxide, water, and new biological cells. The organisms remove dissolved oxygen from the water to accomplish this aerobic biodegradation. Oxygen in the water is replaced by natural aeration. If too much organic material is discharged, the rate at which dissolved oxygen is utilized will be much greater than the rate at which it is replaced. Under these conditions all dissolved oxygen will be consumed and aerobic conditions will no longer exist. This will be fatal to most fish and many other aquatic species. While these effects are primarily associated with the discharge of organic materials, reduced nitrogen compounds (e.g., ammonia) will undergo similar aerobic reactions. Other compounds that react with oxygen (e.g., reduced sulfur comounds) can deplete the dissolved oxygen with the same result.

Nonbiodegradable toxic organic and inorganics, such as salts and heavy metals, cannot be assimilated or destroyed by natural processes. Therefore their concentrations must be maintained below detrimental levels by limiting their discharge to natural waters.

Deep-Well Injection

Disposal of industrial liquid wastes by deep-well injection into underground strata is widely practiced. Its appeal is that wastewaters can be removed from the immediate environment with relatively little treatment. However, subsurface injection is not a waste destruction technology. It simply provides an underground repository for long-term storage and isolation of wastes in the pores of geological formations that already contain nonusable water.

Injection-well technology is firmly established. The chemical industry, for example, has for many decades pumped salt brines from deep geologic formations, extracted their chemical values, and then returned the brines to the formations. Hardware includes surface treatment equipment (e.g., pH adjustment and solids filtration), high-pressure pumps, monitoring instrumentation, and subsurface well casings of high integrity. Formations used for disposal may be hundreds or thousands of feet underground. Identification of acceptable strata and establishment of operating procedures require heavy involvement of the geotechnical sciences. Injection programs must be designed to assure isolation of the wastes for centuries.

Not all geologic formations are suitable for waste injection and not all wastes are physically or chemically compatible with available formations. Candidate waste fluids must generally be of low viscosity and free of suspended solids.

The practice to date has included injecting nearly all conceivable fluid compositions. Under the like-to-like approach, fluids such as saline water and brine that have been pumped from the ground are returned essentially unchanged without the introduction of foreign components. Other liquids with compositions similar to those of the natural fluids are prime candidates for injection. Practice has also included injection of foreign constituents, including a wide range of chemicals present in industrial process wastewaters. Both rather innocuous and highly toxic compounds have been deep-welled, in small and large volumes and at low and high concentrations. Typical wastes include acids, pickling and plating wastes, salt solutions, and by-products from organic chemicals production.

The practice of injecting toxic compounds underground has been the subject of considerable discussion. No clear resolution of the issue has been reached but recently gross environmetal insults (such as Love Canal) have impressed on society the potential hazards of storing toxic chemicals underground. With increasing emphasis on positive destruction of toxics to form inert compounds, the trend is toward using deep-wells only for those constituents that are relatively stable and nontoxic.

The disposal capacity for deep-well injection should be considered and managed as a limited long-term resource. Further it must be recognized that waste storage in underground strata may be for decades or centuries but is not necessarily permanent or risk-free. Also, all the reactions that may occur underground at the ambient temperatures and pressures there are not known.

Adverse environmental impacts will occur if the waste escapes from the formation intended to retain it. Since wastes will travel in the formation and can reach natural or man-made openings in the formation and escape into surrounding aquifiers, they may travel further or rise to the surface.

Stabilization/Solidification

Stabilization/solidification are terms used to indicate any process that converts a liquid, sludge, or semisolid waste into a chemical or physical form that will prevent or limit to acceptable levels the release of a hazardous material to the environment. The objective of most stabilization/solidification processes is to immobilize the hazardous waste, thereby making it environmentally safe for landfill.

Chemical fixation, cementation, and encapsulation are terms used to identify the general types of processes used in stabilizing/solidifying wastes. Chemical fixation refers to any process that immobilizes (fixes) the waste by chemical reaction with a solidification agent and that results in the waste being chemically bound or embedded in a solid matrix at the molecular level. Cementation also refers to the binding together of a waste and solidification agent to form a solid mass. The binding may be accomplished with or without a chemical reaction between the two components. Encapsulation is any process that immobilizes the waste by coating it with or enclosing it within an impermeable and insoluble solid material.

The success of any stabilization/solidification process depends on how well the stabilized waste will resist leaching in a disposal environment. Resistance to leaching depends on how mobile the waste component is when exposed to a leaching agent and/or how well the waste is isolated from the agent. The mobility or isolation of a waste is dependent on two major factors, the strength of the chemical bonds between the reacted waste and the solid-matrix material and the physical strength and structural integrity of the solid matrix. The ideal stabilization process would therefore result in a waste that is completely chemically bound in the molecular structure of a solid matrix that is impervious and impermeable. Obviously, the ideal stabilization process is not always technically achievable or economically attractive.

Stabilization is accomplished by treating waste slurries or sludges with a variety of solidification agents. Solidification agents presently used in chemical fixation and encapsulation processes may be classified as either organic (asphalt, urea-formaldehyde resins, polyolefins, epoxy resins, and polyester resins) or inorganic (Portland and lime-pozzolan cements, lime-based mortars, and silicates).

Because of their ability to absorb and react with large quantities of water, inorganic solidification processes are generally compatible with aqueous waste systems. Most inorganic stabilization processes are based on cementation reactions. It is possible in chemical fixation processes to have three forms of waste immobilization: chemical bonding, matrix entrapment, and encapsulation.

Organic solidification processes differ from inorganic processes in that they do not generally involve a chemical reaction between waste components and the solidification matrix. The principal mechanisms of waste immobilization in organic stabilization processes are matrix entrapment and encapsulation. In most polymeric processes the long-chain molecules of the polymer are linked together to form a multivoided sponge that "traps" the waste. Wastes stabilized by these mechanisms are leachable if contacted by a leaching agent; therefore the physical strength and integrity (permeability) of the solid matrix are of primary importance in these processes. If the solid matrix is porous, liquids can diffuse through, leaching out waste.

Both organic and inorganic stabilization processes share the common problem of specificity for waste components and sensitivity to reaction conditions. High-pH waste may prevent some reactions (urea-formaldehyde solidification), whereas certain other compounds such as sulfates or salts may inhibit the formation of a strong matrix structure. These factors place a heavy demand on process identification, formulation, testing, and control and indicate the need to consider all steps in the waste stabilization process beyond the actual chemical fixation and encapsulation steps.

Depending on the volume of waste to be stabilized and the process to be selected, storage and handling of waste and solidification agents can be a significant part of the total process. Large-volume, continuous-flow processes require storage silos for cement, lime, silicates or other additives, dry-powder conveying and mixing systems, and possibly lime pulverizers. The storage requirements for polymeric types of solidification are not so significant. Most organic stabilization processes are batch-type operations.

Pretreatment of the waste before the solidification process is a frequent requirement. Pretreatment can consist of pH adjustment, volume reduction by removing excess water, or simple resuspension of solids to form a homogeneous slurry. Adjustment of pH may offer an opportunity for codisposal of other wastes. Dewatering of waste sludges reduces the volume of waste to be handled and the amount of raw material required for solidification.

Relatively little technical data are available in current literature concerning specific wastes that have been successfully treated by commercial waste stabilization processes. This is partially due to the proprietary nature of many processes and to the lack of uniform test methods with which to measure success.

The status of waste stabilization/solidification technology can be characterized as currently being at a low-to-moderate technical level, with indications that it is moving into an intense development era that is or will be highly technical. As currently developed, however, stabilization/solidification has proved to be technically and economically feasible with only a limited number of hazardous waste types, and there is concern that some of them may not be stable for geological time. This is especially true for most organic solidification processes. Existing waste solidification methods developed primarily for the nuclear materials industry are being closely evaluated for their general applicability for the disposal of hazardous industrial wastes.

Even with the present limitations, stabilization/solidification technologies must be recognized as having strong potential for rendering a significant portion of the broad hazardous waste profile innocuous, particularly those inorganic materials that are difficult to handle. Therefore stabilization should be considered as a normal step before landfilling any wastes with leaching potential. The cost-effectiveness relationships will need to be continually evaluated for individual wastes as the treatment technology advances.

Land Farming

Land farming of organic, biodegradable, industrial wastes can be an environmentally sound waste management practice if careful consideration is given to a number of factors in order to minimize any adverse environmental impact. This method of disposal involves the application of liquid, sludge, or solid wastes onto or beneath the surface of a vegetated or non-vegetated area and then mixing the waste with the soil. Organic constituents in the waste are biodegraded by naturally occurring soil microorganisms near the soil surface. The decomposition produces innocuous end products, such as carbon dioxide and microbial cell mass. Refractory organics may be bound chemically in the soil. Inorganic constituents, such as salts and metals, are adsorbed onto the soil by physical and chemical phenomena and are immobilized. When crops are grown, the vegetation uses some of the biodegraded waste materials as nutrients.

Evaluation Factors for Site Selection--

General factors that should be evaluated before a site is selected for use as a land-farming area include ground water conditions at the area under consideration, soils, topography, climate, and surrounding land use.

The condition of the ground water is one of the more important factors to be evaluated before a site is chosen for land farming as a waste disposal operation. Areas in which there is locally shallow, potable ground water should be avoided. Such areas generally have relatively permeable soils and underlying strata that would allow any residual materials from the waste degradation and possibly undegraded waste materials to percolate through the soil and reach the ground water.

The types of soil usually considered best suited for waste disposal by land farming are those that are deep, have a large total surface area, and contain much clay and organic matter to absorb and filter the wastes.

An area is generally considered suitable for land farming if it has a slope of less than 5%. As the slope increases beyond 5%, runoff and erosion problems tend to increase. However, a perfectly flat or 0% slope area would not be ideal, as rainfall would accumulate or pond in the disposal area, cause anaerobic conditions that would lead to odor production, and create a hydraulic head, or driving force, that would push any residual contaminants into the subsurface (possibly to area ground waters).

Areas that have high net evaporation, moderate 24-hr, 25-yr frequency maximum rainfall, and medium temperatures are best suited for waste disposal by soil cultivation.

Ideally, a land-farming site should be located in an isolated area to preclude the possiblity of complaints, if and when anaerobic conditions and accompanying odors arise due to accidental overapplication or extended periods of extremely wet weather. If the area under consideration is not reasonably well isolated, a buffer zone and visual buffers such as shrubbery or fencing should be provided.

Waste Application Rate--

The waste application rate is of critical concern when waste disposal by land farming is either in use or under consideration. Two factors that should be known in detail to determine the optimum waste application rate for a particular site are waste composition and cation exchange capacity.

Each waste stream to be land-farmed must be analyzed to determine the application rate of that waste. It is very important that the waste material be analyzed for concentrations of all the metallic elements plus chloride, phosphate, and total nitrogen.

Ground water contamination can be prevented by incorporating a film lining ~ 3 ft under the landfarm area. A leachate collection system is also incorporated so that all water percolating through the land farm is collected and monitored before being discharged to natural waters. This system is termed a "perched bed" system.

Within the operational constraints mentioned above, land farming can be considered to be a viable disposal option for some fraction of the total hazardous waste profile. However, it requires large land areas and must be closely monitored to assure that no problems develop.

Secure Landfill

Land disposal is the most common method used for municipal and industrial wastes, including many hazardous materials. Compared with other disposal methods, landfilling has been relatively inexpensive; but emerging regulations and civil actions have reduced the attractiveness of landfill as a disposal practice for hazardous and other materials that could affect the environment. Over the years numerous cases of ground water contamination from land disposal operations have developed. Unfortunately, only recently has society come to realize the gravity of the problems that exist. However, despite these difficulties, land disposal in some improved form will be an important component of hazardous waste management technologies for a long time into the future.

A landfill, as opposed to an open dump, utilizes engineered burying of wastes in which consideration is given to geological, hydrological, and climatic conditions at the site; to the type, quantity, and physical properties of the materials being buried; and to the ultimate use of the land after the landfill site is closed.

A secure landfill is one in which additional precautions are taken to control leachate and surface drainage, either by selecting a site naturally shielded from surface and ground water or by using various types of liners, barriers, covers, and impoundments. The most important single consideration in selecting a landfill site is to protect the quality of associated natural water, whether it occurs on or under the land surface. A naturally secure landfill is one with no nearby ground water or one that is situated on bedrock, shale, clay, or other impervious material that will prevent the seepage of leachate into ground water. In areas where naturally secure sites do not exist, the landfill area is lined with natural or synthetic materials and leachate collection systems are incorporated.

Landfill sites have historically been classified according to their ability to control leachate and surface drainage. Design requirements are a function of soil type and proximity to ground water. The basic principles of landfill design and operation were developed years ago (although not widely practiced). Within the past few years additional techniques have been developed to provide more positive protection of ground waters and to prevent migration of pollutants into the environment, particularly from hazardous materials.

Although a wide variety of liquid and solid wastes have been landfilled in the past, the most satisfactory wastes are inert inorganic solids. Such wastes do not contain organics and, because of limited water content, pose minimal leaching problems. Wastes to be landfilled should have long-term stability.

Liquids and sludges containing free liquids should be stabilized before they are accepted into landfills. Drums and other containers cause problems when the containers deteriorate; therefore, drums of liquids are excluded from most landfills. In most landfill operations these materials will be limited to only those quantities that can be readily adsorbed or absorbed by the solids and held without any free liquids. Consideration must be given to potential degradation of landfill liners by liquids and sludges.

The placement of organic chemical sludges or solids in the landfill is usually considered to be less environmentally acceptable than positive destruction, such as by incineration. Ideally, each waste should be reviewed relative to its particular hazardous properties, and the most effective destruction technologies should be given primary consideration before a long-term storage approach is selected.

Wastes that can detonate or explode must be deactivated before they are submitted for land disposal. This type of waste, which can be categorized as "bombs," should not be landfilled since sooner or later serious safety and environmental problems will probably result.

Plans are required for monitoring and controlling surface water and ground water. Drainage facilities must be provided to divert surface and subsurface water away from the landfill site, and the runoff from landfill surfaces should be collected and treated or contained and quality-checked before it is discharged. Leachate collection systems should be installed and plans should be made to monitor and record variations in quality. The base and walls of the site should be lined, and materials should be available to cover the site to prevent rainwater infiltration.

The use of landfills for disposal of hazardous wastes is becoming more regulated. Proposed guidelines for hazardous waste disposal contain landfill design and construction details that are quite rigorous. In essence a totally contained, isolated operation is required in all cases. Containment barriers must be provided around and under the site to positively protect the ground water. Ground water and leachate must be monitored for contamination. High-water protection from flooding must also be provided.

Solar Evaporation

Solar evaporation of wastewaters and sludges has proven to be an effective and economical method of wastewater treatment and sludge drying, although its application is limited by climatological considerations. Liquid sludges are distributed in sludge drying beds, where the process of evaporation reduces the moisture content of the sludge. In a well-operated system the discharge of aqueous wastewaters to receiving waters can be minimized if not completely eliminated.

The primary criterion in site selection for solar evaporation processes is the net amount of precipitation, which is defined as the difference between the annual average amounts of precipitation and evaporation. The use of solar evaporation as a treatment process is restricted to areas where evaporation exceeds precipitation.

PHYSICAL-CHEMICAL SEPARATIONS

Emulsion Breaking

An emulsion may be defined as a two-component liquid system in which one component (referred to as dispersed or discontinuous) is dispersed as finite globules within the second component (referred to as continuous or external), which is the surrounding liquid. This description is sometimes broadened to include colloidal dispersions, which consist of a finely divided solid phase dispersed in a liquid medium. Emulsion breaking refers to the separation of emulsions into two distinct phases.

The most common emulsions consist of an oil phase dispersed in an aqueous medium. The stability of the emulsions is primarily a function of the chemical and physical characteristics of the two phases. Important characteristics include electrical surface charges on the dispersed phase, the presence of chemical emulsifying agents, the size distribution of the oil droplets in solution, and the relative densities and viscosities of the dispersed and continuous phases. In nearly all the emulsion breaking devices or processes one or more of these physical/chemical characteristics are altered. These devices or processes may be categorized into the following major groups: density differential separation, filtration coalescence separation, chemical separation, electrical separation, and thermal separation.

Density Differential Separators--

Density differential separators are the oldest and most common treatment devices used for oil/water separation. They are based on the specific-gravity difference between the oil droplets and the water phase. Either gravity or centrifugal force is used for phase separation.

Density differential separators are generally used as a pretreatment device in removing oil dispersions with large particle-size distributions and densities that are significantly different than those of the water phase in which they are suspended. Application is limited to waste streams in which the oil particles are present in relatively high concentrations.

American Petroleum Institute (API) separators are effective for the gravitational removal of oil globules larger than 0.015 cm in diameter. API separators consist of inlet and outlet sections, a pretreatment stage, separating stages, baffles, skimming devices, and flight scrapers. Plate separators are similar to API separators but have some type of plates inserted into the separation chamber to reduce the maximum rise height of the oil globules and to promote oil droplet coalescence. Centrifugal separators, which include both centrifuges and cyclones, induce separation by centrifugal forces due to rotational movement.

Gas flotation is another variation in which the separation is enhanced by the attachment of microscopic gas bubbles to the oil globules. Gas bubbles may be introduced into the solution by one of several techniques, including dispersed air, dissolved air, vacuum desorption, or electrolysis. Chemical coagulents are frequently used in conjunction with gas flotation units to increase oil removal efficiency.

Each of the aforementioned type of density differential separators has been demonstrated to be an effective emulsion breaking process. API and plant separators are economical and simple to operate. They have few moving parts, require very little power, and need minimal operator attention. Gravity-type devices are able to handle large flow rates with varying influent oil concentrations without process upsets. Plate separators, however, are prone to have clogging problems when handling a waste stream with a high solids content. Centrifugal separators may have substantial power and maintenance requirements and are considerably more complicated to operate than API and plate separators, but they have the advantage of being usable in limited space. The chief advantages of gas flotation units include the fairly high quality of effluent attainable and the ability to handle a high solids flux.

Filtration/Coalescence Separation--

Filtration/coalescence emulsion breaking devices with the most applicability are the granular-media and fibrous-media types. Both granular-media and fibrous-media filters rely principally on the phenomenon of coalescence of the dispersed media.

A wide variety of materials, including sand, anthracite, plastic, ceramic, glass, metals, and graphite, have been used as filtration media for granular filters. The oil removal mechanism in granular filters involves both direct filtration and induced coalescence. Filtered oil and solids are removed by backwashing.

Fibrous-media coalescers are the most common devices for breaking dilute oil/water emulsions. Temperature and chemical effects must be taken into consideration when selecting the packing materials for fibrous-media coalescers.

Filtration/coalescence devices require either backwashing or media replacement when flux rates reach unacceptable levels. If backwashing is required, backwash water will have to be treated and disposed of. Fibrous-media coalescers are subject to failure because of solids plugging problems and chemical poisoning.

Chemical Separation--

Chemical emulsion breaking processes attempt to neutralize surface electrical charges and/or alter interfacial films so that coalescence may readily occur. Emulsions may be stable because of their natural surface charges and oil droplet size distribution. However, many emulsions used in industrial processes are purposely stabilized by the addition of an emulsifying agent, a chemical that alters either interfacial tension or surface charge in an oil/water dispersion.

Emulsions that contain emulsifying agents are broken by the addition of an antagonistic ion or emulsifier. Anionic and cationic emulsifying agents are not mutually compatible, since they have opposing electrical charges. Therefore they tend to react with each other and their emulsifying effect is nullified. Since nonionic emulsifiers are completely covalent, they are practically immune to neutralization by anionic and cationic agents. Emulsion breaking of solutions stabilized by a nonionic emulsifier may be accomplished by adding certain emulsifiers with opposing properties or by changing the solution pH. Once an emulsion has been destabilized by the addition of antagonistic emulsifiers, the oil droplets are removed from solution by other physical/chemical processes. This procedure typically consists of adding a coagulant, such as alum or a synthetic polymer, followed by gas flotation.

A second chemical method of breaking emulsions is the widely used acid-alum-lime process. Sulfuric acid is added to reduce the pH of the emulsion. The addition of alum at this point will result in charge neutralization since most oil emulsions are negatively charged. Lime is then added to the emulsion to raise the pH into the 6 to 8 range, which hydrolyzes the aluminum ions and forms an aluminum hydroxide floc that sweeps the destabilized oil out of solution. For some specific applications, iron salts, such as ferric chloride and ferrous sulfate, are used instead of alum for charge neutralization and floc formation. Sodium hydroxide instead of lime may be used for pH adjustment.

Chemical treatment followed by dissolved air flotation can be used to remove 70 to 93% of the oil from stable chemical emulsions that are not readily broken by physical means. Waste streams containing high concentrations of suspended solids, which foul other devices, are adequately treated by chemical means.

However, there are several disadvantages associated with chemical treatment. If coagulants are used to separate a destabilized oil/water emulsion, a chemical sludge will be produced that may have high disposal costs. In systems utilizing acid for pH adjustment, corrosion problems may be severe.

A number of plants are presently using chemical emulsion breaking. The difficulty of operating a chemical emulsion breaking process results primarily from the variability of the flow and the concentration of the oil in the waste stream. If the waste stream is highly variable, frequent adjustments must be made to the chemical doses that are added to the stream. An adequately sized equalization tank preceding the treatment process will help to reduce influent stream variability.

Electrical Separation--

Separation of oil/water emulsions by electrophoretic and magnetic means has been investigated to a very limited extent. High cost and low liquid flow rates discourage the use of such devices.

Electrophoretic devices establish a strong electrical field in which the negatively charged oil particles migrate to the positively charged electrode. The emulsion is broken up by charge neutraliztion at the anode, and the oil/water phases separate under the influence of gravity. This process has been reported to yield 97% recovery of emulsified oil from a feed stream.

Magnetic separation of emulsions requires the addition of an oil-soluble, water-insoluble ferrofluid to the waste streams. The waste stream is then passed through a packed bed placed in a magnetic field. The packed bed is composed of magnetic particles or screens. The oil droplets are retained within the device while the water passes through. The oil may be recovered in concentrated form by shutting off the magnetic field.

Thermal Separation--

Thermal separation is used in conjunction with other physical-chemical methods to break up oil/water emulsions. Increasing the temperature of an aqueous solution from 20 to 50°C will yield a 45% reduction in the viscosity of the aqueous phase. This results in an increase in the rise velocity of an oil particle and has a dramatic effect on the performance of devices utilizing density differential separation techniques. The efficiency of filtration devices and chemical separation processes is also increased at elevated temperatures.

Volatilization

For the purpose of this evaluation volatilization is defined as a process by which the components of a liquid mixture are separated into a liquid-phase product and a gas or vapor-phase product by virtue of the differences in volatility of the components. In general, volatilization can be divided into four major categories: fractional distillation, steam stripping, evaporation, and inert-gas stripping.

Fractional Distillation--

Distillation is a separation technique applicable to the separation of components from virtually any liquid mixture, including aqueous-organic and organic-organic liquids. To produce a significant degree of separation by distillation, a number of successive vaporization and condensation operations are usually required. This is accomplished by causing the boiling liquid and a saturated vapor to contact each other countercurrently in a distillation column, either through dispersal of the gas in the liquid or through dispersal of the liquid in a continuous gas phase.

A typical distillation operation requires a still pot or reboiler (heat exchanger) to provide the heat for vaporization of the feed, a distillation column (packed or containing trays for vapor liquid contact), and a condenser to condense the vapor product and provide liquid reflux to the top of the column. Materials of construction for distillation equipment depend on the physical properties of the system.

Distillation can be carried out batchwise or continuously. In batch column distillation, the mass of material to be rectified is heated to the boiling point in a still pot and the vapors are passed upward through a column and then condensed. The distillation is carried out until the desired recovery of the more volatile component or components is achieved at the desired purity. In continuous distillation, feed is continuously added at an intermediate point in the column, part of the reflux stream is removed as overhead product, and a bottoms product is withdrawn continuously from the still pot or reboiler. The degree of separation in a continuous distillation is a function of the number of stages in each section of the column, the boiling rate, and the reflux ratio.

Distillation is also an integral part of many waste treatment and/or recovery processes, such as carbon adsorption and solvent extraction. A general application, other than as part of these processes, would be for separation and purification of compounds for sale from waste mixtures.

Steam Stripping--

Steam stripping is a special case of distillation that is directly applicable to removing volatile organic and/or dissolved gases from wastewater. The preferred application is for removal of organic compounds or solvents present at dilute concentrations in wastewater.

A typical steam stripping system for the removal of a compound that forms a heterogeneous azeotrope with water includes a heat exchanger to preheat the feed, a distillation column containing trays or packing for mass transfer between the liquid and vapor phases, a condenser, and a decanter. The materials of construction for a stripping system will depend on the nature of the specific components to be separated.

Evaporation--

Evaporation is the removal of solvent as vapor from a solution or slurry. The vapor may or may not be recovered, depending on its value. The end product may be a solid, as could be the case with evaporation of water from sludge, but the transfer of heat in the evaporator must be to a solution or suspension of the solid in liquid if the apparatus is not to be classed as a dryer. Evaporators are similar to stills or reboilers of distillation columns except that no attempt is made to separate components of the vapor.

Aside from heat transfer considerations the selection of the evaporator type best suited for a particular service is governed by the characteristics of the feed and products. Materials of construction are chosen to maximize heat transfer and product quality while minimizing corrosion and erosion problems, which are frequently more severe in evaporators than in other types of equipment.

A preferred application of evaporation is the removal of water from sludge to produce incinerable solids.

Inert-Gas Stripping--

Volatile materials can be removed from a solution by passage of a gas, such as air or nitrogen, through the mixture. The volatile component or components transfer from the liquid phase to the vapor phase. This can be accomplished stagewise in a column similar to that used for steam stripping. A gas stripping system normally requires that the gas from the top of the column be treated in some manner to remove the stripped material before the gas is discharged to the atmosphere or sent to a flare or incinerator for destruction. In some systems using air or nitrogen to strip organics from wastewater, organics are removed from the gas by carbon adsorption.

Gas stripping may be preferred over steam stripping when the contaminants to be removed are very volatile and a column is not required. Capital and carbon regeneration costs for gas stripping are normally higher than the capital and steam costs required for steam stripping, depending on the wastewater flow and volatility of the contaminants. In many cases the off-gas (air) can be flared or sent to an incinerator, thereby eliminating the cost of gas treatment.

All the volatilization processes discussed in this section are proven technologies depending on the nature and requirements of the separations involved. Distillation as a separation technique is used throughout the chemical process industry. Steam stripping is also a widely used technique for the removal and/or recovery of organic compounds from wastewater.

Adsorption

Adsorption processes, and particularly those using activated carbon, are finding increased use in wastewater treatment for removal of refractory organics, toxic substances, and color.

In adsorption, dissolved substances in the wastewater are attracted to and adhere to a solid adsorbent surface. The primary mechanisms for adsorption are a combination of the hydrophobic nature of the solute (dissolved organics) in the wastewater and the affinity of the solute for the solid. The solubility of the dissolved organics is the property most directly related to hydrophobic behavior, with organics of low solubility being most readily adsorbed. The affinity of the solute (sorbate) for the solid (adsorbent) is due to a combination of electrostatic attraction, physical adsorption, and chemical adsorption.

Adsorption systems consist of columns arranged in series or parallel and loaded with granular activated carbon or synthetic polymeric adsorbents.

The design of adsorption systems requires a knowledge of the equilibrium capacity (isotherm) of the adsorbent for the solutes to be removed and the overall rate of adsorption, factors normally determined by laboratory techniques.

Adsorption systems differ mainly in the method by which the adsorbent is regenerated. The conventional method for regeneration of spent activated carbon is to thermally oxidize the adsorbed organics in a controlled atmosphere that minimizes the oxidation of the carbon itself. In-place nondestructive techniques using steam, solvent, or a change in the pH are also used. Polymeric adsorbents are normally regenerated by solvent or pH change, or a combination of both.

Solvent regeneration of adsorbent involves the use of a solvent phase to desorb the organic chemicals from the adsorbent. The solvent is then removed (as in conventional solvent vapor recovery systems) by steam. The only requirement is that the organics to be removed be soluble in a common solvent. The pH-change method involves adsorption of an ionic organic chemical as the free acid or base and elution of it from the adsorbent as the ionized salt by using an alkaline or acidic regeneration stream. Steam has long been used to desorb volatile organics from vapor-phase adsorbers. Application of steam regeneration of activated carbon to wastewater treatment is an extension of this technology. Of the three in-place nondestructive regeneration processes, solvent regeneration is the most applicable to a wide variety of waste problems.

Adsorption with powdered activated carbon (PAC), which is normally combined in a biological system, might be considered as a separate process for the removal of toxic or priority pollutants. The cost of PAC is significantly less than that of granular activated carbon; so for special cases, such as the necessity of removing a toxic chemical, the loaded PAC might simply be incinerated.

Adsorption is applicable to almost any dilute aqueous organic liquid. In general activated carbon has been found to adsorb a wide variety of organic chemicals. Only the smaller organics, C_1 and C_2, and large complex molecules adsorb poorly or not at all. In between is a broad range of chemicals that can be removed from water by activated carbon.

In many cases, carbon adsorption is the best available technology for removing organic compounds up to concentrations of ~1% from water. The removal efficiency is a function of the design and the adsorbability of the specific organics. Almost any effluent quality desired can be obtained in a properly designed and operated system.

In general adsorption is more versatile than other technologies for removing contaminants from wastewater, such as stripping, extraction, ion exchange, and electrodialysis. Ion exchange and electrodialysis would normally be specific for ionic species. Steam stripping would be applicable to low-boiling solvents or liquids that azeotrope with water. Extraction would normally require higher feed concentrations (depending on the specific distribution coefficient) and would be much more sensitive than adsorption to variable feed composition. Also, unlike extraction, solvent regeneration of activated carbon is not limited to water-immiscible solvents.

In general in-place nondestructive regeneration offers advantages over thermal regeneration. By preventing physical transport of the adsorbent, losses due to attrition are avoided. Nondestructive regeneration also offers the opportunity to recover valuable organics that have been adsorbed.

A process is being investigated to remove heavy metal ions, dissolved organics, phenols, and cyanides from industrial sewage by adsorption. The method uses carbon, but rather than using activated carbon, it uses low rank lignite coals, an abundant natural resource in North America.

Lignite coals cost approximately one-tenth the amount of activated carbon and are reported superior to activated carbon for adsorption of selected contaminants. After exhaustion as an adsorbent, the coal can be fired as fuel for its energy value. The process has been tested at the bench scale using simulated wastes and is at a stage for expansion to a pilot scale.

A new regeneration technique using microwaves to regenerate molecular sieves, silica gel, and other adsorbents has been patented. Advantages cited are that the adsorbed materials can be recovered in concentrated form and regeneration itself takes place in minutes rather than hours. That time reduction might allow use of smaller or fewer adsorption beds. This technology is presently available for licensing.

Extraction

Solvent extraction is the separation of the constituents of a liquid solution by contact with another immiscible liquid. If the components of the original solution distribute in different amounts between the two liquid phases, a certain degree of separation will result. The degree of separation can be increased by multiple contacts of the two phases. The more general type of extraction refers to a liquid-liquid system in which the primary attractive forces between the solvent and solute are nonionic in nature.

The first step in a typical solvent extraction process is to bring the two liquid phases, feed and solvent, into intimate contact to allow solute transfer. The phases must then be separated. A mixer settler represents one equilibrium stage, where the fluids are mixed, extraction occurs, and the insoluble liquids are settled and separated. A cascade of stages using mixer settlers may be arranged when more than one stage is needed, or multistage equipment with the equivalent of many stages may be incorporated into a single device.

The two output streams from the settler are the solute-laden solvent (extract) and the feed stream less whatever solute has been removed (raffinate) but possibly containing some solvent. The extract is fed to a distillation column to separate the solvent from the solute. The recovered solvent can be sold, recycled, incinerated, etc., depending on the specific situation. Solvent reuse is generally necessary for economic reasons.

Solvent recovery from the treated stream (raffinate) is required in an extraction process if solvent losses would otherwise add significantly to the cost of the process or cause environmental problems when the raffinate is discharged. Solvent recovery from the raffinate may be accomplished by stripping, distillation, adsorption, or other suitable processes.

Solvent extraction is theoretically applicable for the removal of almost any solute from any liquid solution. In actual applications of aqueous waste treatment, solvent extraction will most often be competitive with steam stripping and, to a lesser degree, with adsorption. Solvent extraction is not cost competitive with biological treatment unless the value of the recovered solutes is significant.

Extraction is competitive with carbon adsorption when the recovery value of the solute is relatively high or the concentration of solute in the aqueous waste is relatively high. The cost of carbon regeneration makes extraction more competitive with carbon adsorption as the waste concentration increases.

Solvent extraction is usually applicable to liquid organic wastes when distillation is impractical because of azeotrope formation or relatively high energy requirements.

Solvent extraction is a highly technical operation requiring the linking of a number of standard unit operations such as mixing, decantation, distillation, etc. It is unlikely that solvent extraction alone will reduce the concentration of organics, especially toxic substances, to levels that will permit them to be directly discharged. Some form of polishing treatment will often be required. There are no insurmountable technical problems with solvent extraction. The most difficult problem is finding a solvent that best meets a list of desired qualities, including low cost, high extraction efficiency, low solubility in the raffinate, easy separation from the solute, adequate density difference with the raffinate, and no tendency for emulsion formation, and that is nonreactive and nonhazardous. No one solvent will meet all the desired criteria; so compromise is usually necessary.

Liquid/Solids Separation

There are a variety of techniques used to perform liquid/solids separation. In many applications the objective is removal of solid contaminants from wastewaters before they are discharged. Liquid-solids separation processes are also used in conjunction with other unit operations, such as biological treatment and chemical precipitation. Liquid-solids separation plays a major role in reducing the volume of waste sludges before ultimate disposal.

The descriptions that follow have been classified into three major subgroups: screening, clarification-thickening, and dewatering.

Screening-- Screens are employed primarily to protect downstream mechanical equipment from problems associated with handling oversized solid particles. Waste treatment applications commonly use rotating-drum screens, vibrating screens, and stationary screens. A rotating-drum screen consists of a revolving cylinder with a screen supported on the structure. Vibrating screens include both rectangular and circular units, and generally dewater solids better than other types of screens. They are usually recommended for separation of small particles. In a stationary screen design the screen slope varies from 15 deg from the vertical at the top of the screen to 45 deg at the bottom of the screen. The advantage of the stationary screen is that it has no moving parts; the disadvantages include high hydraulic-head loss and potentially high operating-labor requirements to keep the screen clean. The stationary screen is suited for removal of large particles that exhibit good flow characteristics without plugging the screen. The solids removal on any screen depends on the nature of the waste, the type of screen, the screen opening, and the hydraulic and solids loading to the screen.

Clarification and Thickening--

Clarification and thickening liquid-solids separation processes are used to perform the following functions:

- As a pretreatment technique for removing from waste streams organic or inorganic impurities that would otherwise interfere with or damage subsequent processes.

- As a final treatment or polishing step to produce a high-quality effluent suitable for direct discharge.

- As a thickening device to reduce the volume of sludge to be handled and to produce a thicker sludge for better operation in subsequent sludge dewatering processes.

The effluent quality is an important consideration in the first two functions, whereas the concentration of the thickened sludge is important in the third function. The effluent from the thickening process in conventional secondary treatment operations is normally returned to the treatment system. Commonly used processes for clarification-thickening are sedimentation, dissolved air flotation, high-rate filtration, and centrifugation.

Sedimentation may be defined as the removal of solid particles from a suspension through gravity settling. The nature of the solids and their concentration are the major factors affecting the settling properties. The sedimentation process can accomplish both clarification of the wastewater and thickening of the settled solids. In both cases an adequate surface area is the key design parameter for satisfactory operation. In general the surface area required for clarification is related to the settling velocity of the solids. Typical sedimentation equipment includes a feed pump, a sedimentation tank, flow distribution and overflow structures, sludge and scum removal mechanisms, and a sludge pump. Chemicals are frequently added to the sedimentation process to improve the settling rate.

Dissolved air flotation is used for removal of suspended solids, oils, and greases from wastewater and for separation and concentration of sludges. In this process the waste stream is pressurized in the presence of sufficient air to approach saturation. When the pressurized air-liquid mixture is released to atmospheric pressure in the flotation unit, minute air bubbles attach themselves to the suspended solids and become enmeshed in the floc particles. The air-solids mixture rises to the surface, where it is then skimmed off. The clarified liquid is removed from the bottom of the flotation unit.

The high-rate filtration process, long applied in water treatment, is becoming widely used for wastewater treatment, both in upgrading existing plants and in designing new, advanced-treatment facilities. A typical filter consists of a layer of sand or other granular medium supported on a gravel bed, which rests on an underdrain system that is used to collect the filtered water. In the filtration process, wastewater is passed through the medium, either by gravity or under pressure, and the solids are deposited on the medium. As the operation progresses, the pressure drop across the bed continues to increase, to the point that the ability of the medium to remove suspended solids is impaired. A backwashing process is then necessary to clean the medium.

The centrifugation process uses centrifugal force to speed up the sedimentation rate of solid particles. Centrifuges are generally used for dewatering rather than for thickening. Since the centrifugal thickening process can require substantial maintenance and power costs, it has been used only where space limitations or sludge characteristics make other methods unsuitable. The thickened sludge from centrifugation is normally in a fluid stage that can be pumped.

The kinds of centrifuges that have been successfully used for sludge thickening are the solid-bowl, disk-nozzle, and basket types. Each type of centrifuge may have its own potential applications and disadvantages. Process variables (such as feed solids concentration, feed rate, and chemical requirements) and machine variables (speed, pool depth, etc.) should be carefully evaluated.

Dewatering--

Dewatering can be classified as a process in which a slurry containing solids (commonly called sludge) with an approximate solids concentration of 2 to 5 wt % is dewatered to produce a cake with a solids concentration of 12 to 40%. The cake solids concentration is a function of the nature of the sludge and the type of the dewatering process.

Sludges are generally dewatered by pressure, vacuum, or belt filtration or by a horizontal-bowl decanter type of centrifugation.

Pressure filtration is a batch process using a series of chambers lined with the filter medium. Sludge is pumped into the chambers, where an applied pressure of about 8 atm forces the liquid through the filter medium into discharge ports, with the solids retained in the chamber.

Vacuum filtration is a process in which solids are deposited on the filtration surface by means of an applied vacuum. In most applications the filter medium is supported on a drum that rotates in a vat of the slurry being dewatered.

The belt filtration process dewaters sludges through a combination of gravity, pressure, and shear forces. The chemically conditioned sludge is applied to a moving continuous belt, where the free water drains through the synthetic medium. A second belt gradually converges toward the first belt so that dewatering is achieved by the pressure applied by the belts and by table rolls behind both top and bottom belts. Finally, the two belts converge and travel through an S-shaped path around several rollers. Shear forces are applied to the solids in this zone before the dewatered cake is removed.

The horizontal-bowl decanter centrifuge consists of a rotating horizontal cylindrical bowl and a helical conveyer that rotate at slightly different speeds. The sludge is usually introduced near the base of a conical section called the beach zone. Due to the rotational speed difference the solids move by the helical conveyer along the bowl to the beach zone. The solids move up the beach toward the discharge by the conveyer while the centrate moves down the beach toward a weir located at the other end of the centrifuge.

The unit processes described above are used for dewatering a wide variety of sludges. A brief evaluation of the different types of filters used and of the centrifugation process follows.

Since the solids handling capacity of the belt filtration method is least affected by the feed solids concentration, it is usually used to dewater relatively dilute sludges such as biological and metallic hydroxide sludges. It is frequently recommended as a dewatering technique when maximum cake dryness is not the paramount consideration. The advantages of a belt filter include relatively low capital and operating costs and operational simplicity.

A precoated vacuum filter is used on sludges that are both difficult to dewater and require high chemical conditioning dosages, for example, organic sludges. The principal advantage of this dewatering technique is its capability of handling sludges with varying dewatering characteristics; the disadvantages include high power consumption, the need for precoat storage and handling, and the relatively large equipment required.

A pressure filter generally produces the driest cake and therefore should be considered when incineration of the dewatered sludge or landfilling is involved. It is also suitable for relatively thick sludges.

Centrifugation is most often used for sludges that have good dewatering characteristics.

Chemical Precipitation and pH Neutralization--

These two methods for treating industrial wastewater are described below.

Chemical precipitation--Chemical precipitation is a process in which chemicals are added to the wastewater to react with such constituents as heavy metals to form insoluble products that can be removed in a solids-liquid separation process. When the precipitate formed is a colloidal dispersion that cannot be removed by conventional sedimentation or filtration processes, coagulants are added to the wastewater to effect destabilization and aggregation of dispersed materials so that the precipitate can be removed. Coagulant aids are used to decrease the time for floc formation, to increase the size, density, and toughness of the flocs, and to extend the effective pH range of the coagulant dosage.

The development of a design for a precipitation process usually includes a laboratory study to determine the precipitating chemical dosage, reaction time, coagulant and coagulant aid dosage, pH, and solid-liquid separation characteristics.

The widest application of chemical precipitation has been for the removal of metals. However, the process is theoretically applicable to any substance that can be transformed into an insoluble form (e.g., soaps, sulfides, and fluorides). Metals are generally precipitated as the hydroxide or carbonate species. When extremely low residual metal concentrations are required, precipitation of metal sulfide may be the preferred treatment.

A continuous precipitation-coagulation process is most applicable to those cases in which the waste characteristics are uniform; the basic operating procedure is to establish the chemical feed rates and the pH controller set points. A batch process is most applicable when the waste volumes are low and the waste characteristics are highly variable. A batch system generally has two or more tanks, each one designed for a typical period of operation. Continuous treatment systems have smaller tank requirements and are therefore more economical than batch systems.

pH neutralization--Acidic and alkaline plant effluents are characteristic of many manufacturing and processing operations. These discharges represent a serious source of stream pollution because they can alter the normal pH of natural-water courses. Sulfuric, hydrochloric, and nitric acids comprise the bulk of waste acidity, with sulfuric acid predominating.

Most regulatory codes specify that the pH of any effluent discharge not be lower than 6 nor higher than 9 units. Neutralization is also generally required in biological treatment systems and is accomplished by the addition of an alkali or an acid as required to effect the desired pH adjustment.

The chemical characteristics of a waste solution, in terms of composition and concentration of components, influence the neutralization reaction between an acid and an alkali and may affect sludge production and scale formation. Consequently, chemical characteristics exert a dominant role in the selection of an applicable neutralizing agent and in the determination of process conditions.

The agent selected for neutralization is an important part of the overall plant costs, as well as the plant design, construction, and operation. Commonly used commercial alkalis are sodium hydroxide, sodium carbonate, high-calcium hydrate, dolomitic hydrate, high-calcium quicklime, dolomitic quicklime, high-calcium limestone, and dolomitic limestone.

Sludge handling and disposal may be a major fraction of the cost of a neutralization operation. In most cases the cost of sludge disposal is related to the volume and to the ease with which the sludge can be dewatered. A full evaluation of sludge properties and handling costs should be factored into the selection of a neutralization system.

Self-neutralization, which involves a blending of various waste streams to yield a total plant effluent within the desired pH range, should be given prime consideration whenever practical. This type of neutralization may be accomplished by proper management and operation, since it can eliminate or minimize neutralization reagent costs and result in a major saving.

Membrane Separations--

Specific compounds can be transported through a membrane from one liquid phase into another for such applications as removal and/or recovery of specific compounds, brine concentration, and water desalination. The ability of a membrane to transport one component in a liquid stream at a higher rate than another component is transported is determined by its thickness, density, and pore diameter. The transportation rate of specific compounds through membranes depends on the driving force involved, such as mechanical forces, electromotive forces, and chemical potential or concentration forces. The physical design of the membranes and associated equipment is strongly related to the major driving force causing the separation.

For individual waste-treatment applications, membrane separation technologies must be regarded as developmental or emerging and have not yet been demonstrated for broad commercial application. Success has been achieved for specific applications such as when the feed stream composition and process conditions can be controlled. Membrane fouling can be a significant problem. Because of these considerations membrane separation technologies must presently be considered as not applicable for an industrial waste-treatment facility handling a wide range of waste materials.

The different types of membrane separations used are discussed below.

Dialysis--Dialysis is, in effect, liquid extraction with a membrane. Solutes or components of liquid streams will diffuse through porous or nonporous membranes; the net flow of the solute is from the more concentrated stream to the more dilute stream. The rate of transport is directly proportional to the concentration difference of the two solutions separated by the membranes. The human kidney uses this process to eliminate toxic components from the blood.

Dialysis can apply to industrial waste treatment when a specific component must be removed from a liquid stream but bulk contact with another miscible or immiscible phase is not desired. Normally, severe temperature, suspended solids, and organic limitations exist and must be taken into consideration.

Reverse osmosis--If a water solution containing a solute is placed next to a membrane in contact with a body of pure water, the chemical potential or concentration difference will begin to transport the water through the membrane into the solute phase. If the pressure applied to the solute-containing stream is greater than the osmotic presure, water will flow back through the membrane. This application of reverse osmotic pressure is the basis for reverse osmosis (RO) separations.

In general, reverse osmosis is a very effective means of separating dissolved ionic solids and nonionic solids from water solutions by transporting the water through the membrane. Solutions containing less than 10% total dissolved solids and more typically 2% can be processed. The membranes in use today have severe restrictions on the pH, oxidizing potential, suspended solids and turbidity, and temperatures of the feed. Extensive pretreatment is often necessary to render an RO feed suitable for processing. Failure to adequately pretreat will almost certainly result in membrane failure and require its replacement.

It is not generally possible to use pure organic feeds to RO systems since the plastic materials used for membranes and internals may mechanically deform or dissolve. Aqueous streams with significant organic concentrations can be considered. Aqueous and organic two-liquid-phase emulsions are possible feeds as long as solid phases are not present or formed during concentration. Strong acids and bases cannot be fed to current systems. Many other ionic compounds, including heavy metals, may be satisfactory feeds.

By far the largest area of application of reverse osmosis today is the production of very pure potable or process water from brackish ground water, sea water, or dilute solute wastewater. In cases where fouling can occur, the cost of membrane replacement prevents widespread application.

Ultrafiltration--Ultrafiltration (UF) can be thought of as a reverse osmosis unit in which the solute separation begins at higher molecular weights. Most low-molecular-weight compounds in a feed will pass through the membrane with the bulk water phase, whereas the high-molecular-weight compounds concentrate. RO and UF systems operate in different pressure ranges.

The major advantages of the UF system over the RO system are that it requires less pretreatment and that it can handle much more corrosive feed streams. UF modules are manufactured from materials that are much more chemically stable than RO module materials and can be operated in strong acids and bases, oxidizing feeds, and high levels of organics. Their pretreatment is often less rigorous than RO pretreatment since powerful cleaning agents and high temperatures may be used to clean fouled systems. Scales do not tend to form since inorganic salts typically are not concentrated. UF often is used as a pretreatment for RO systems.

Electrodialysis--If a solution of ionic compounds or salts was placed next to a solution of pure water but separated by a membrane containing fixed charges, such as an ion-exchange membrane, the osmotic pressure would drive the ions through the membrane into the salt-free water. This process will continue until the concentrations in each stream are equivalent. In electrodialysis (ED) electrical direct current is used to transport the ions.

An important function of ED is its ability to concentrate the ions removed. A feed containing 5 wt % NaCl (normally not a candidate for RO) may be separated into one stream containing 1.5 wt % and another stream containing 71% of the total salt at 21 wt % concentration. ED not only desalts one of the streams, but also results in a high concentration of brine. Also, ED is used to manufacture dilute streams containing very few ions. Some systems are designed to achieve very low concentrations in the dilution, whereas others are designed to generate brines of very high concentration. Optimal equipment selection depends on the specific ED application.

Electrodialysis does not have the sensitivity to suspended solids that reverse osmosis has since the ions are transported mostly through the membranes, but ED membranes are susceptible to fouling. Existing membranes are not acid sensitive; however, only a few are claimed to be stable in strong alkalis (>2% NaOH). Electrodialysis membranes cannot operate in strong oxidizing streams but can sometimes be used under mild oxidizing conditions. Operating temperatures are presently limited to about 40°C.

Electrodialysis has large-scale application for production of potable water from seawater and brackish water, particularly in Japan. Industrial applications include recovery of a range of inorganic and organic chemicals from specific process streams.

Ion Exchange--

Ion exchange has been applied widely in the chemical processing industry and other industries for both processing streams and waste streams. Ion exchange is an adsorption process in which the solid adsorbent is a resinous material. Natural ion-exchange adsorbents (zeolites) exist; however, most industrial processing utilizes synthetic adsorbents. These synthetics normally are polymeric solid matrices onto which functional groups are added by reaction. The dissociation and equilibrium constants of ion-exchange adsorbents are almost entirely determined by the density and type of functional groups attached to the solid structure.

The effluent quality achievable with ion exchange is excellent. Since it is an unsteady-state adsorption process and equilibrium normally is achieved rapidly, it is sometimes the only available technology capable of attaining very high effluent quality.

Ion-exchange systems usually have to be regenerated since the replacement cost of the resins is quite high. Regeneration is usually accomplished by use of an acid or a base. Although valuable ions may be recovered from the feed, the high dissolved solids content often necessitates that the effluent be discarded.

Ion exchange is normally a batch process. It can be used on a continuous basis by employing a system to move the resin or by using multiple channel valves so that one section is being loaded while another section is being regenerated.

Ion exchange is normally applicable to aqueous streams containing ionic compounds. The major limitations of ion exchange are limits on suspended solids, the presence of materials that tend to solidify, gels and solids forming in the beds, high temperatures, oxidizing streams, and streams containing organic fouling agents. Relatively high concentrations of some organics (e.g., methanol) can be tolerated but organics will sometimes cause swelling of the polymer and plugging or other mechanical problems.

SECTION 6

DISCUSSION AND CONCLUSIONS

DISCUSSION

The New Jersey Industrial Waste survey indicated that 9 million tons per year (TPY) of industrial waste is generated in New Jersey and 26% of the waste generated is disposed of off site. For the categories discussed, the off-site disposal percentage varies from near 0% to almost 100%. It was quickly confirmed that the industrial waste disposed of off site cannot be estimated from waste-generated data. Except for the header page all survey questions were directed toward obtaining specific off-site disposal data that would assist in projecting the needs for regional disposal facilities.

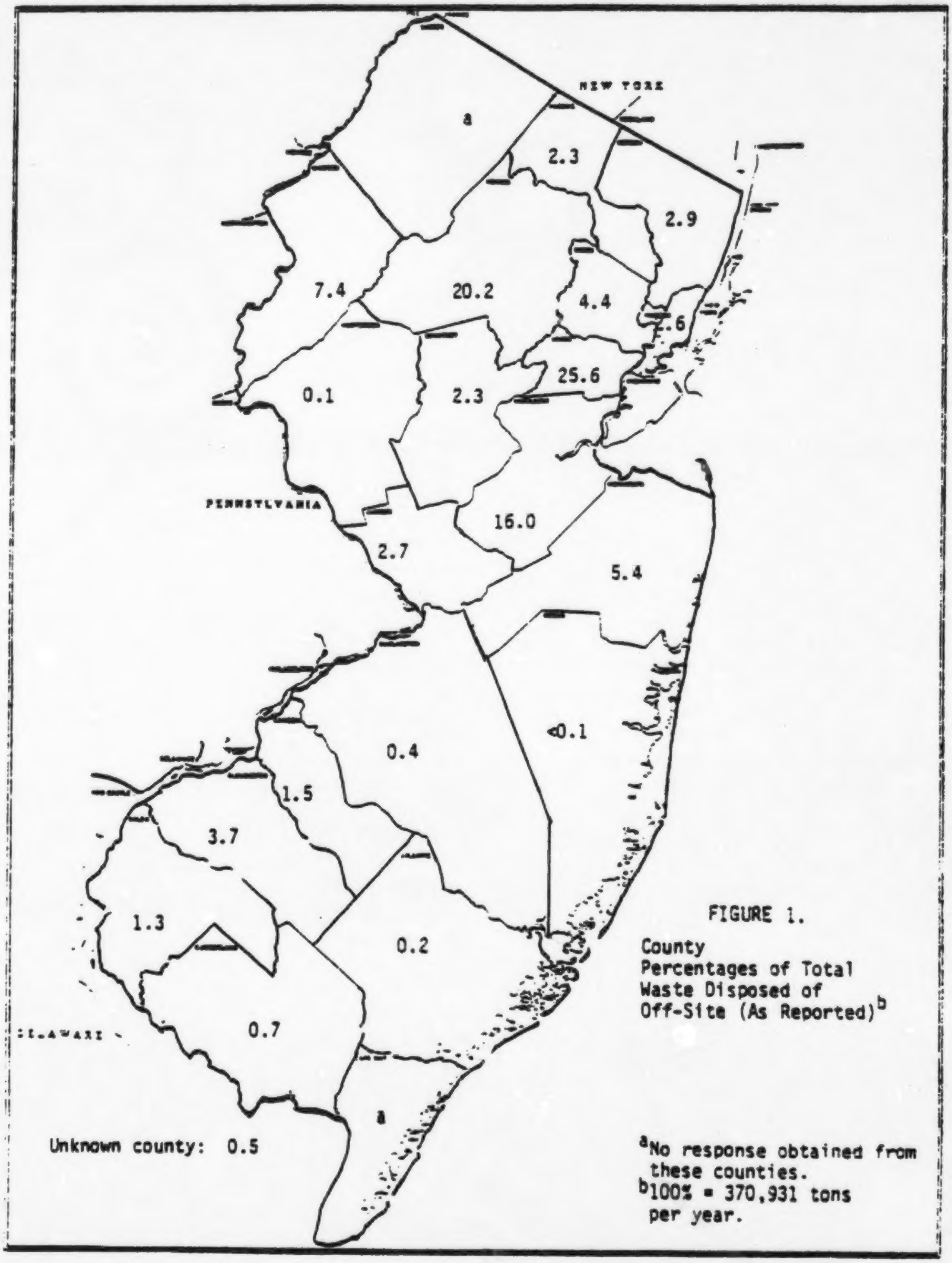
Figure 1 shows the distribution by county of off-site industrial waste as reported (Table 4). Figure 2 shows the distribution by county of the total off-site waste 5-yr projection (Table 7). Because of a variety of anticipated industry improvements, the 5-yr state-wide off-site waste projection is approximately 14% less than the present state-wide projection.

To determine the treatment and disposal methods that would be practical for regional facilities and the potential capacity for those systems, a cross comparison was made between the off-site waste characteristics as listed by Tables 11 through 21 and the treatment technology matrices presented by Table 22. This determination must be heavily influenced by the off-site waste disposal methods currently being used and the respondents' predictions of future disposal methods for their off-site wastes. Many scenarios can be further illuminated by comparison with other areas of the study or back-reference to the respondent surveys. The combinations of the cross investigations are infinite but are strictly limited by the constraints of time and budget.

For the purpose of this study it is assumed that all wastes accepted at a regional facility will be considered hazardous. The survey header sheets used to create Tables 4 and 5 included industrial and municipal trash, but trash was excluded from all other tables throughout the study. As shown by Table 10 the respondents indicated that 19,304 TPY of waste (excluding trash) may be going to municipal landfills. A back-check on these wastes revealed that they are primarily inorganic solids that could apparently be classified as nonhazardous.

A review of the 5-yr projection of off-site disposal methods predicted by the respondents indicates a cause for concern that hazardous secure land-

STATE COUNTY OUTLINE MAP **NEW JERSEY**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3.7
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0.2
0.7
DELAWARE
a

Unknown county: 0.5

FIGURE 1.

County Percentages of Total Waste Disposed of Off-Site (As Reported)[b]

[a] No response obtained from these counties.

[b] 100% = 370,931 tons per year.

STATE COUNTY OUTLINE MAP **NEW JERSEY**

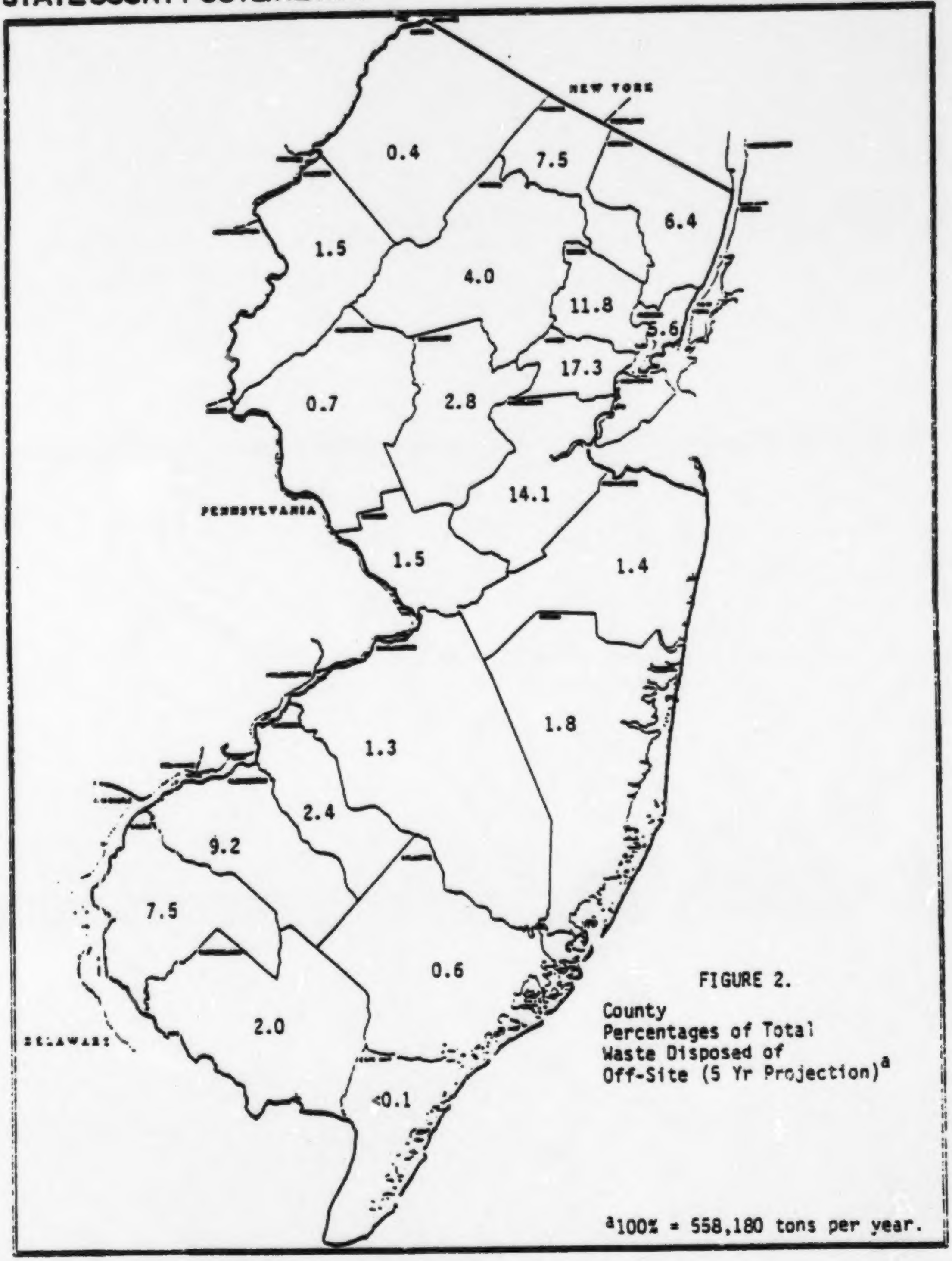
NEW YORK
0.4
7.5
6.4
1.5
4.0
11.8
5.6
17.3
0.7
2.8
14.1
PENNSYLVANIA
1.5
1.4
1.8
1.3
2.4
9.2
7.5
0.6
2.0
DELAWARE
<0.1

FIGURE 2.

County Percentages of Total Waste Disposed of Off-Site (5 Yr Projection)[a]

[a] 100% = 558,180 tons per year.

fills are expected to continue to be the most common method of off-site disposal. This concern is magnified by the realization that over half of the waste destined for landfill contain organic chemicals at a concentration of greater than 10% and most at organic chemical concentrations of greater than 30%. These wastes are difficult to stabilize/solidify. Significant usage of chemical/physical treatment and resource recovery has been anticipated by the respondents, so it does not appear practical to assume that much of the waste projected for landfill could be diverted to resource recovery. Incineration is the clearly practical and environmentally safe choice for destruction of waste with organic chemical content.

The respondents forecast that only 92,000 TPY of the 5-yr projected waste will be disposed of using thermal treatment. A more environmentally acceptable alternative would be to incinerate the high organic waste now destined for landfill. This would bring the total for incineration to 153,000 TPY or approximately 50% of the total waste for which the respondents indicated a disposal method. If it is assumed that the same ratio would apply to the 251,384 TPY with no method indicated, the total waste projected for incineration would be approximately 278,000 TPY.

By following the same pattern of logic, the breakdown of the disposal methods for the total off-site 5-yr projection would be as follows:

	%	Adjusted %	TPY
Incineration	50	36	200,944
Secure landfill	16	11	61,400
Other land treatment	12	9	50,236
Resource recovery	16	11	61,400
Physical treatment	17	12	66,982
Chemical treatment	21	15	83,727
Biochemical treatment	9	6	33,491
	141	100	558,180

Since several wastes had more than one potential disposal method indicated on Table 10, these wastes were counted more than once. This accounts for the total of 141% in the first column above. The second column adjusts the estimates to 100%. Before adjustment the figures can be considered as projected maximums.

From Table 7 the projected totals for organic liquid, organic slurry, and organic solids equal 431,063 TPY. If the above resource recovery, physical treatment, and chemical treatment total of 212,109 TPY was removed from the 431,063 TPY, it would leave 218,954 TPY of waste that could logically be considered as feed for incineration. This tends to confirm the projection that at least 200,000 TPY of incineration capacity will be required.

Referring to Table 19, it is logical to assume that the wastes most appropriate for incineration will include those reported to have high heat values, although a significant quantity of low heat value wastes will also be disposed of by incineration. Using the high side distribution of heat values for the 5-yr waste projection listed by Table 19, it is estimated that 200,000 TPY of waste will generate 3,783,388 million Btu/yr.

A review of the physical form of the waste and containers as shown by Tables 8 and 9 indicates that the best incineration systems for use at the regional facilities would be multi-purpose rotary kilns with high temperature secondary combustion chambers and gas cleaning systems. The kilns should be designed to handle all wastes, including steel drums, and should also be expected to incorporate energy recovery. With an operating factor of 85% and assuming a kiln system design capacity of 80 to 90 million Btu/hr, six rotary kiln units would be required to dispose of the projected waste.

Large secure landfill facilities will be required with stabilization/solidification processes to provide maximum ground water and environmental protection. The primary hazardous component will be heavy metals, including heavy metals from incineration system ashes and precipitated metals from scrubber water and other precipitation systems. A review of Tables 12, 14, 15, and 16 shows that a very high volume of waste contains heavy metals but only a relatively small amount of waste has a high enough concentration of metals to be categorized as a metal waste or sludge. Although it may be possible to recover some metals, this is questionable and cannot be determined from this survey. It is estimated that approximately 60,000 TPY will require disposal in a secure landfill.

As discussed in Section 4 the survey responses project a total off-site disposal of more than 47,000 TPY acid and more than 43,000 TPY of base to be disposed of off site. Table 11 lists 24,749 TPY acid and 37,649 TPY base. Neutralization facilities will be required as well as biochemical treatment facilities to accommodate the estimated 27,000 TPY indicated by Table 10. Although no off-site wastes are presently disposed of by landfarming, Table 10 indicates that biodegradation by landfarming has potential and should be considered.

As shown by Table 13, 56,308 TPY of used oil waste is projected for off-site disposal. The extent of recovery cannot be projected from the survey data, but potential oil recovery should be considered in regional facility design. As a minimum, high quality waste oil should be segregated for either fuel use or as an auxiliary heat source for incineration systems.

As shown by Table 17, 38,791 TPY of waste that has solvent recovery potential is forecast to be shipped off site. Many of the most commonly used solvents are present in high volumes, and high recovery potential appears to be indicated. This would require blending, distillation, and drying facilities. The extent of potential recovery cannot be established from this survey.

The battery limits cost estimate for the rotary kiln incineration system recommended for regional facilities is $150 to 230/ton. The basis for this estimate is given in Appendix G.

A review of disposal costs in New Jersey indicated that the average 1982 charge for incineration was $270/ton and that the average secure landfill cost was $300/ton not including stabilization/solidification which would add at least $40/ton.

There has been no attempt throughout this study to assess the disposal facilities available for off-site waste. Some of the disposal methods currently being employed may be unsatisfactory for long-term disposal. This is especially true of currently reported hazardous waste landfill practices.

Many off-site waste disposal methods currently being employed are completely satisfactory and are expected to continue. Recovery systems in the areas of solvent, oil, and metals are already in operation and, in some cases, pay the waste generating facility for the feedstock received.

CONCLUSIONS

The total off-site waste 5-yr projection for New Jersey is 558,180 TPY. Based on the study results it is projected that the most practical disposal methods for the off-site waste at regional facilities will be incineration and secure landfill. There will be a need for chemical/physical treatment including neutralization, precipitation, and biotreatment. The need for recovery systems for solvents, oils, or metals will depend on the availability of other facilities providing these functions.

The incineration systems should be multi-purpose rotary kilns, and the secure landfill is expected to use a stabilization/solidification process, primarily for heavy metals disposal. A review of the cost for these disposal services showed the 1982 disposal charges to be $270/ton for incineration and $300/ton for secure landfill, not including stabilization/solidification which would add at least $40/ton.

The off-site waste county distribution map (Fig. 2) should be helpful for determining the number and location of regional facilities. The most important factor in siting regional facilities will probably be selection of acceptable sites for secure landfill.

An appropriate route to the establishment of practical regional facilities to serve New Jersey industry might be to start one or two regional operations with one 80 to 90 million Btu/hr rotary kiln capable of accommodating approximately 40,000 TPY with provisions to increase the state-wide capacity to more than 200,000 TPY with 6 rotary kilns if needed.

The initial secure landfill capacity might be 20,000 TPY with room for expansion to a state-wide capacity of 60,000 TPY. The chemical/physical treatment facilities such as neutralization, precipitation, and biochemical treatment should also be nominal until the demand is established. It may be advisable to curtail the installation of recovery facilities for solvent, oil, or metals until the additional need for this service can be established. Consideration should be given to providing for the addition of a land farming system.

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APPENDIX A

RESEARCH AND DEVELOPMENT COUNCIL OF NEW JERSEY
INDUSTRIAL WASTE STUDY TASK FORCE
AND
QUESTIONNAIRE SUBCOMMITTEE

Mr. Allan Jacobs, Chairman; Metcalf and Eddy
Dr. John Liskowitz, Chairman, Questionnaire Subcommittee; New Jersey Institute of Technology
Ms. Dorothy Bowers; Merck & Company
Mr. George Caplis; Westinghouse, Lamp Div.
Mr. Paul Cheremisinoff; New Jersey Institute of Technology
Mr. Elpidio De La Teja; Thomas J. Lipton, Inc.
Mr. Patrick Deeney; Bristol-Myers Products
Mr. Fred Ellerbusch; Bristol-Myers Products
Mr. Hank Graulich; National Starch & Chemical
Dr. Martin Gurvitch; FMC Corporation
Ms. Georgia Harnett; New Jersey Business & Industry Association
Mr. James Hauer; Lehn & Fink
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Mr. F. X. James; Warner-Lambert
Mr. Wayne M. Kachel; Exxon Research & Engineering Co.
Ms. Anne L. Krueger
Mr. George Kush; SCA Chemical Services
Dr. Charles W. Lawrence; New Jersey Energy Research Institute
Mr. Charles J. Lind; Bell Labs
Mr. John Mahon; Schering Corporation
Mr. Edward Marra; New Jersey Department of Environmental Protection
Mr. Alfred Mazzacca; Biocraft Laboratories
Dr. Richard Moon; SCA Chemical Services
Dr. L. E. Netherton; BASF
Mr. John O'Dell; Drew Chemical
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Mr. Arthur Sarkisian; ITT-Rayonier
Mr. Paul Schultz; Allied Corporation
Mr. Robert Scola; U.S. Army AARADCOM
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Dr. R. V. Trense; Exxon Research & Engineering Company
Mr. George Tyler; New Jersey Department of Environmental Protection
Mr. Ronald Venturi; Public Service Electric & Gas Company
Mr. R. J. Ward; Union Carbide
Mr. Paul E. Wyszkowski; Bell Labs
Mr. Harold Zahrndt; National Starch & Chemical
Mr. Richard Albers; Modern Transportation
Mr. Samuel J. Faiello; SJF Associates/R&D Council

Respondent No. ____________

APPENDIX B

NEW JERSEY INDUSTRIAL WASTE SURVEY

Total Waste Generated

Site Location County ________

Total Employees at the Site ________

Total Administrative and Auxiliary Employees ______

R&D Lab Employees included in Admin. and Aux. ______

Primary SIC Code ______ Total Prim. Code Employees ______

SIC Sub. Code ______ Employees ______

SIC Sub. Code ______ Employees ______

SIC Sub. Code ______ Employees ______

Remaining Primary SIC Code Employees ______

Total Employees at the Site ______

The following wastes are presently treated or disposed on-site, off-site at your company-owned facility, or off-site at a contractor facility. (See Table I for category definition.)

Category	Total Tons/Yr	On-Site or Company-Owned Off-Site	Contractor Off-Site	Portion of On-site with Potential >50% for Future Contractor Off-Site Disposal Tons/Yr
Aqueous Inorg. Liq.				
Aqueous Org. Liq.				
Inorganic Liquids				
Organic Liquids				
Inorganic Slurry				
Organic Slurry				
Inorganic Solid				
Organic Solid				
Industrial Trash				
Municipal Trash				

All the remaining questions concern wastes that are now going off-site to a non-company-owned facility or that have a greater than 50% potential for future off-site disposal at a regional (non-company-owned) facility.

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Respondent No.________

NEW JERSEY INDUSTRIAL WASTE SURVEY

Specific Waste Description

Off-Site Disposal

All the following questions should be answered using a separate set of sheets for each waste now going off-site to a non-company-owned facility or having a greater than 50% potential of going to a future regional waste facility. Please describe the waste as it leaves your facility.

1. Common Waste Designation (e.g., flammable liquid; metal sludge; plant trash; lab waste)

   ____________________________Generating SIC Code__________

2. Number of Employees Associated with SIC Code__________County__________

3. Which category, as defined by Table I, best describes the waste?

   ☐ Aqueous Inorganic Liquid
   ☐ Aqueous Organic Liquid
   ☐ Inorganic Liquid
   ☐ Organic Liquid
   ☐ Inorganic Slurry
   ☐ Organic Slurry
   ☐ Inorganic Solid
   ☐ Organic Solid
   ☐ Industrial Trash
   ☐ Other________________

4. At 60°F, how would you describe the waste?

   Liquid ☐ Solid ☐ Sludge/Slurry ☐ Gas ☐ Other ☐ Specify________

5. How does the waste presently leave your plant?

   ☐ Bulk Solids
   ☐ Steel Drum
   ☐ Fibre Drum
   ☐ Bulk Liquids
   ☐ Other (Please explain):________________________
   ____

6. What is the present rate of disposal for this waste? Select the most appropriate rate of disposal and amount:

	Wt.	Volume
a. Mass and volume/day	______	______
b. Mass and volume/week	______	______
c. Mass and volume/month	______	______
d. Mass and volume/yr	______	______
e. Mass and volume/shipment	______	______

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6. (Cont'd)

Number of shipments/yr ___________ Specific gravity ___________

Annual waste generation rate___________(tons/yr)

7. What do you expect to happen to the present quantities of this waste in the next five years?

	%
Increase	_____
Decrease	_____
Stay Same,	_____

8. Where is the waste presently disposed of:

☐ On-site but >50% potential for future off-site

☐ Off-site (contract disposal) and expected to continue off-site

☐ Off-site but >50% potential for future on-site disposal

9. How is the waste disposed of? (See Table III.)

Enter the present disposal numbers from Table III____________________

Enter the disposal numbers that appear applicable for future disposal____

10. Which category numbers in Table II best describe this waste?

General characteristics________________________________

Specific characteristics________________________________

Special handling______________________________________

Other characteristics (describe)__________________________

____

11. What are the main constituents of the waste?

Compound	Wt. %
______________________________	_____
______________________________	_____
______________________________	_____
______________________________	_____

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12. Please mark the appropriate boxes relative to the waste stream composition (best estimate).

	Weight Percent							
A. Overall Composition	0	0-1	1-10	10-30	30-50	50-70	70-90	>90
Organic	☐	☐	☐	☐	☐	☐	☐	☐
Inorganic	☐	☐	☐	☐	☐	☐	☐	☐
Water	☐	☐	☐	☐	☐	☐	☐	☐
B. Organic Composition								
Carbon	☐	☐	☐	☐	☐	☐	☐	☐
Chlorine	☐	☐	☐	☐	☐	☐	☐	☐
Other Halogen	☐	☐	☐	☐	☐	☐	☐	☐
Sulfur	☐	☐	☐	☐	☐	☐	☐	☐
Nitrogen	☐	☐	☐	☐	☐	☐	☐	☐
Phosphorous	☐	☐	☐	☐	☐	☐	☐	☐
Other__________	☐	☐	☐	☐	☐	☐	☐	☐
C. Inorganic Composition								
Sodium Chloride	☐	☐	☐	☐	☐	☐	☐	☐
Florides	☐	☐	☐	☐	☐	☐	☐	☐
Other Salts	☐	☐	☐	☐	☐	☐	☐	☐
Heavy Metal Compounds (excluding aluminum and iron)	☐	☐	☐	☐	☐	☐	☐	☐
Other__________	☐	☐	☐	☐	☐	☐	☐	☐

13. If the waste is aqueous acid_____or aqueous base_____, please check and specify the type____.

14. Would this waste be classified as one of the following used oil categories?

Yes ☐ No ☐

If yes, please check:

Used vehicle oil _______ Organically contaminated oils ________

Used industrial lubricating oil _________ oily sludge ____________

Other (Specify)____

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15. Would this waste be classified as one of the following metal wastes: Yes ☐ No ☐

If yes, please check:

Single Metal Sludge________ Mixed Metal Sludges__________

Single Metal Slag or Dust________ Mixed Metal Slag or Dusts_________

16. Please check those metals that are present in your waste and circle the major metals.

☐ Berylium
☐ Cadium
☐ Chromium
☐ Copper
☐ Nickel
☐ Silver
☐ Zinc
☐ Antimony
☐ Thallium
☐ Mercury
☐ Selenium
☐ Arsenic
☐ Lead
☐ Magnesium
☐ Barium
☐ Manganese
☐ Iron
☐ Cobalt
☐ Aluminum
☐ Tin

17. Does this waste have solvent recovery potential? ☐ Yes ☐ No
If yes, indicate the solvents present at 10% or higher concentration in the waste:

☐ Xylene
☐ Methanol
☐ Toluene
☐ Acetone
☐ Perchloroethylene
☐ Methylene Chloride
☐ Methyl ethyl ketone
☐ Methyl isobutyl ketone
☐ Trichloroethylene
☐ 1,1,1-Trichloroethane
☐ Freons
☐ Other______________

18. Dissolved solids content ________% (if known)

19. Total Organic Carbon (if known):____________ TOC

20. Chemical Oxygen Demand (if known):_____________COD

21. Is the waste readily biodegradeable? Yes ☐ No ☐
BOD_5 (if known):__________________

22. What is the heat of combustion of the waste in Btu/lb? (best estimate)

<3000 ☐
3000-6000 ☐
6,000-10,000 ☐
10,000-15,000 ☐
15,000-20,000 ☐
Don't know ☐

23. Is the acute toxicity high by:

Inhalation ☐ Dermal ☐ Ingestion ☐

24. Is this waste classified as hazardous according to the RCRA criteria? Yes ☐ No ☐
Please check the appropriate classification box(es), and fill in the waste number.

☐ Ignitable
☐ Corrosive
☐ Extract Procedure (EP) Toxic
☐ Listed

Hazardous Waste RCRA No.____________
(if known)

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Table I. Waste Category Definitions

Aqueous inorganic liquids	<1% organic >99% H_2O and inorganic <10% solids
Aqueous organic liquids	1-10% organic >90% H_2O and inorganic <10% solids
Organic liquids	>10% organic Liquid at 60°F
Organic solids	>1% organic Solids (non-pumpable) at 60°F
Industrial trash	Non-contaminated material: wood, paper, plastics, rags, containers, construction materials, dirt, etc.
Inorganic solids	<1% organic solid (non-pumpable) at 60°F
Organic slurry	>1% organic Pumpable at 60°F >10% solids
Inorganic slurry	<1% organic Pumpable at 60°F >10% solids

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Table II. Waste Characteristics

A. General Characteristics

Inorganic

1. Acid
2. Alkali
3. Metal sludges/slurries
4. Salts and brines
5. Metal finishing solutions (e.g., plating, etching, pickling)
6. Catalysts
7. Flyash
8. Scrubber sludge
9. Water treatment sludge
10. Filter aids and clays
11. Construction debris
12. Tank clean-out residues
13. Off-spec chemicals
14. Returned goods
15. Contaminated soils and sediments
16. Contaminated in solution
17. Other

Organic

18. Used oils/oily sludges
19. Spent solvents
20. Contaminated spill cleanup
21. Biological sludges
22. Sludge/slurry
23. Still bottom residue
24. Spent carbon
25. Tank clean-out residues
26. Metallo-organic
27. Trash (paper, wood, plastic, metal, rubble, etc.)
28. Contaminated trash
29. Lab waste (samples, reagents, etc.)
30. Solid plastics, rubber
31. Contaminated soils/sediment
32. Lagoon sludge/sediments
33. Off-spec chemicals
34. Returned goods

B. Specific Characteristics

35. Cyanides
36. Sulfides
37. Trace organic
38. Trace inorganic
39. Aqueous
40. Chlorinated organics
41. Halogenated organics
42. PCBs
43. Asbestos
44. Organic nitro groups
45. Organic sulfur
46. Metallo-organic (e.g., tetraethyl lead)
47. Polychlorinated biphenyls (PCBs) at >50 ppm
48. Vinyl chloride
49. Metals
50. Alkali metal salts (e.g., Na, K, Li)

C. Special Handling Characteristics

51. Volatile (>1.5 psig at ambient conditions)
52. Flash point, <140°F
53. Pyrophoric
54. Explosive
55. Shock sensitive
56. Unstable peroxide
57. Odor - organic
58. Ordor - inorganic
59. Corrosive
60. High viscosity
61. Suspended solid
62. Waste characteristics change during storage
63. Compatability problems
64. Large bulky waste
65. Pathological
66. Pumpable only when heated to less than 250°F
67. Abrasive

Reactive with:

68. Alakali
69. Acid
70. Oxidizer
71. Water
72. Other

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Table III. Treatment and Disposal Processes

- 100 DESTRUCTIVE
  - 110 Chemical Oxidation
    - 111 Ozone
    - 112 Chlorine
    - 113 Other Halogen
    - 114 Hydrogen Peroxide
    - 115 Other
  - 120 Thermal Treatment
    - 121 Incineration
    - 122 Pyrolysis
    - 123 Boiler Fuel
    - 124 Wet Air Oxidation
    - 125 Cement Kiln
    - 126 Calcination
    - 127 Other
- 200 CHEMICAL TREATMENT
  - 210 Neutralization
  - 220 Precipitation
  - 230 Reduction
  - 240 Hydrolysis
  - 250 Other
- 300 PHYSICAL TREATMENT
  - 310 Adsorption
    - 311 Carbon
    - 312 Ion Exchange Resin
    - 313 Other
  - 320 Membrane Separation
  - 330 Thermal Separation
    - 331 Distillation
    - 332 Evaporation
    - 333 Steam Stripping
  - 340 Solids Separation
    - 341 Centrifugation
    - 342 Filtration
    - 343 Settling/Clarification/Precip.
    - 344 Flotation
  - 350 Liquid-Liquid Extraction
- 400 LAND BASED TREATMENT/DISPOSAL/STORAGE
  - 410 Landfill
    - 411 Sanitary (Munic., unregulated)
    - 412 Hazardous (secure)
  - 420 Land Application
    - 421 Land Spraying (above ground)
    - 422 Land Farming (below ground)
  - 430 Deepwell
  - 440 Ponding
    - 441 Solar Evaporation
    - 442 Surface Impoundment
- 500 RESOURCE RECOVERY
  - 510 Solvent
  - 520 Oil
  - 530 Metals
  - 540 Energy
- 600 STORAGE ON-SITE
- 700 STORAGE OFF-SITE
- 800 BIOLOGICAL TREATMENT

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SIC PRODUCT DESCRIPTIONS

- 20 FOOD & KINDRED PRODUCTS
  - 201 MEAT PRODUCTS
    - 2011 MEAT PACKING PLANTS
    - 2013 MEAT PRODUCTS, PREPARED
    - 2016 POULTRY DRESSING PLANTS
    - 2017 PROCESSING, POULTRY & EGG
  - 202 DAIRY PRODUCTS
    - 2021 BUTTER, CREAMERY
    - 2022 CHEESE, NATURAL & PROCESSED
    - 2023 MILK, CONDENSED & EVAPORATED
    - 2024 ICE CREAM & FROZEN DESSERTS
    - 2026 MILK, FLUID
  - 203 CANNED & PRESERVED FRUITS & VEGETABLES
    - 2032 CANNED SPECIALTIES
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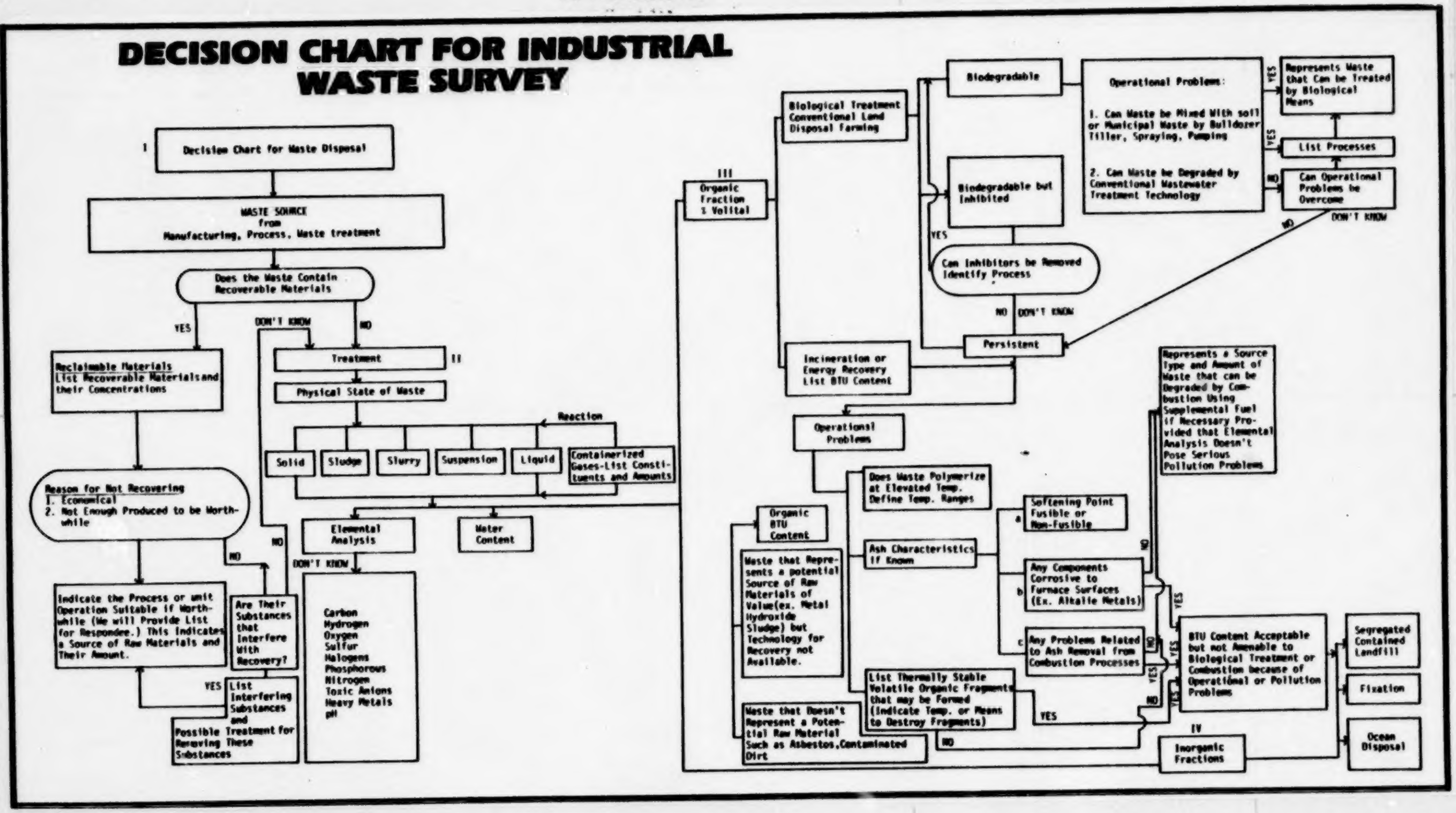
APPENDIX C

METRIC SYSTEM CONVERSION TABLE

To Convert From	To	Multiply By
Btu	Joule (J)	1.055×10^3
Gallons	Meter^3 (m^3)	3.785×10^{-3}
Pound	Kilogram (kg)	0.4536
Tons	Kilogram (kg)	1.016×10^3
Degree Fahrenheit	Kelvin (K)	$t_k = (t_f + 459.67)/1.8$

APPENDIX D


DECISION CHART FOR INDUSTRIAL WASTE SURVEY

I
Decision Chart for Waste Disposal
WASTE SOURCE from Manufacturing, Process, Waste treatment
Does the Waste Contain Recoverable Materials
YES
DON'T KNOW
NO
Reclaimable Materials List Recoverable Materials and their Concentrations
Treatment
II
Physical State of Waste
Reaction
Solid
Sludge
Slurry
Suspension
Liquid
Containerized Gases-List Constituents and Amounts
Reason for Not Recovering
1. Economical
2. Not Enough Produced to be Worthwhile
NO
NO
Elemental Analysis
Water Content
DON'T KNOW
Indicate the Process or unit Operation Suitable if Worthwhile (We will Provide List for Respondee.) This Indicates a Source of Raw Materials and Their Amount.
Are Their Substances that Interfere With Recovery?
YES
List Interfering Substances and Possible Treatment for Removing These Substances
Carbon
Hydrogen
Oxygen
Sulfur
Halogens
Phosphorous
Nitrogen
Toxic Anions
Heavy Metals
pH
III
Organic Fraction is Volital
Biological Treatment Conventional Land Disposal Farming
Biodegradable
Biodegradable but Inhibited
YES
Can Inhibitors be Removed Identify Process
NO
DON'T KNOW
Persistent
Incineration or Energy Recovery List BTU Content
Operational Problems:
1. Can Waste be Mixed With soil or Municipal Waste by Bulldozer Tiller, Spraying, Pumping
2. Can Waste be Degraded by Conventional Wastewater Treatment Technology
S3A
S3A
NO
Represents Waste that Can be Treated by Biological Means
List Processes
Can Operational Problems be Overcome
NO
DON'T KNOW
Operational Problems
Organic BTU Content
Waste that Represents a potential Source of Raw Materials of Value(ex. Metal Hydroxide Sludge) but Technology for Recovery not Available.
Waste that Doesn't Represent a Potential Raw Material Such as Asbestos,Contaminated Dirt
Does Waste Polymerize at Elevated Temp. Define Temp. Ranges
Ash Characteristics if Known
List Thermally Stable Volatile Organic Fragments that may be Formed (Indicate Temp. or Means to Destroy Fragments)
a
Softening Point Fusible or Non-Fusible
b
Any Components Corrosive to Furnace Surfaces (Ex. Alkalie Metals)
c
Any Problems Related to Ash Removal from Combustion Processes
NO
YES
NO
YES
YES
NO
YES
YES
NO
Represents a Source Type and Amount of Waste that can be Degraded by Combustion Using Supplemental Fuel if Necessary Provided that Elemental Analysis Doesn't Pose Serious Pollution Problems
BTU Content Acceptable but not Amenable to Biological Treatment or Combustion because of Operational or Pollution Problems
IV
Inorganic Fractions
Segregated Contained Landfill
Fixation
Ocean Disposal

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EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-660-639
TYPING GUIDE SHEET

APPENDIX E

RESEARCH AND DEVELOPMENT COUNCIL
OF NEW JERSEY

Industrial Waste Study
Task Force
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Metcalf & Eddy
Dr John Liskowitz Chairman
Questionnaire Subcommittee
New Jersey Institute of
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Bristol-Myers Products
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Union Carbide
Mr Paul E Wrasenowski
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Mr Harold Zaninc
National Starch &
Chemical
Mr Richard F Albers
Modern Transportation
Mr Samuel J Faiello
SJF Associates
R&D Council

January, 1983

NEW JERSEY INDUSTRIAL WASTE SURVEY

Dear x x x

When it was announced that New Jersey would construct hazardous waste disposal facilities, the Board of Directors of the Research and Development (R&D) Council of New Jersey agreed that if waste disposal facilities were to be built, then technology-based industry should provide technical guidance to encourage construction of the most practical, useful and affordable facilities.

Thus, the R&D Council, a private association of industrial and academic research laboratories, began a voluntary industrial effort to compile a unique technical data base upon which state government could make critical decisions concerning these facilities. The participants in the voluntary effort are listed on this letterhead.

Unlike traditional studies of this kind, industry is actually guiding and directing this project and is utilizing a consulting firm which has had considerable experience in this field; namely, IT Enviroscience (ITE).

What we hope to do is relate the physical, chemical and biological properties of waste streams to disposal technology options, with or without pretreatment. We are not concerned with the chemical composition of wastes, but with those properties which make them amenable to treatment technologies.

To protect the confidentiality of the questionnaire, we will remove the top sheet which has your name and organization identified on it. The processor of the questionnaire will only be provided the information that follows.

We also will provide you with assistance from one of the members of the industrial waste study task force if needed. Please call R&D Council offices if you want to avail yourself of this assistance.

Thank you.

Sincerely yours,

C. Welles Fendrich, Jr.
Chairman

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APPENDIX F

ESCALATION FACTORS

SIC	State-Wide[a] No. Employees	Respondent No. Employees	SIC Codes Used	Escalation[b] Factor
203	6,225	237	203	26.27
207	1,293	185	See "All remaining"	
208	6,368	51		
229	3,933	272		
239	11,736	98		
264	12,859	498		
275	16,704	320		
281	4,606	1,738	281	2.65
282	4,739	2,800	282	1.69
283	32,777	8,356	283	3.92
284	23,407	4,995	284	4.69
285	4,966	4,635	285	1.07
286	15,517	4,076	286	3.81
287	989	409	287	2.42
289	6,928	872	289	7.94
291	4,846	1,550	291	3.13
299	962	1,034	299	1.0[c]
306	4,556	170	306	25.8
307	30,238	403	See "All remaining"	
322	11,434	603		
331	3,831	230	33	17.09
332	3,552	278		
334	1,007	34		
335	9,156	265		
336	2,388	260		
339	2,181	227		
341	5,056	620	34	15.24
342	8,376	294		
344	12,857	878		
345	4,320	615		
346	7,213	70		
347	3,517	108		
349	12,373	939		
353	4,536	1,162	35	9.06
355	11,323	407		
356	15,153	2,362		
358	7,688	339		
366	30,121	3,985	36	11.73
367	18,983	200		
371	12,529	1,400	See "All remaining"	
384	9,625	1,157		
387	578	124		
422	6,505	25		
492	4,185	100		
501	17,390	67		
734	19,438	69		
739	58,628	3,800	739	15.43
971	d	24,950	971	1.0
999	e	1,249	See "All remaining"	
			All remaining	25.08
Total	523,791	79,516	Total	6.59

[a] County Business Patterns 1981 (US Bureau of Census).

[b] Escalation factor - No. State-wide employees ÷ No. respondent employees.

[c] Actual value - 0.93.

[d] Not listed. Assumed 24,950.

[e] Not listed. Assumed 1249.

APPENDIX G
COST ESTIMATE BASIS
ROTARY KILN SYSTEM

All costs adjusted to January 1982 basis

Capital costs are installed battery limits costs and include:
- Materials handling and storage
- Incinerator feed equipment
- Rotary kiln and secondary combustion chamber
- Ash handling
- Air pollution control

Costs not included are:
- Land
- Site preparation
- Other ancillary facilities (lab, fire protection, roads, guardhouse, etc.)
- Energy recovery equipment
- Waste water treatment equipment
- Permits

Operating costs include:
- Utilities
- Raw materials
- Auxiliary fuel
- Ash disposal
- Labor
- Maintenance
- Insurance and taxes

Operating costs do not include:
- Regulatory compliance

Economic evaluation basis:
- 15 year life
- 12% discount factor
- 6% inflation factor

Operating Basis:
- 85% operating factor (7446 hours/year) at design capacity